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MACHINE

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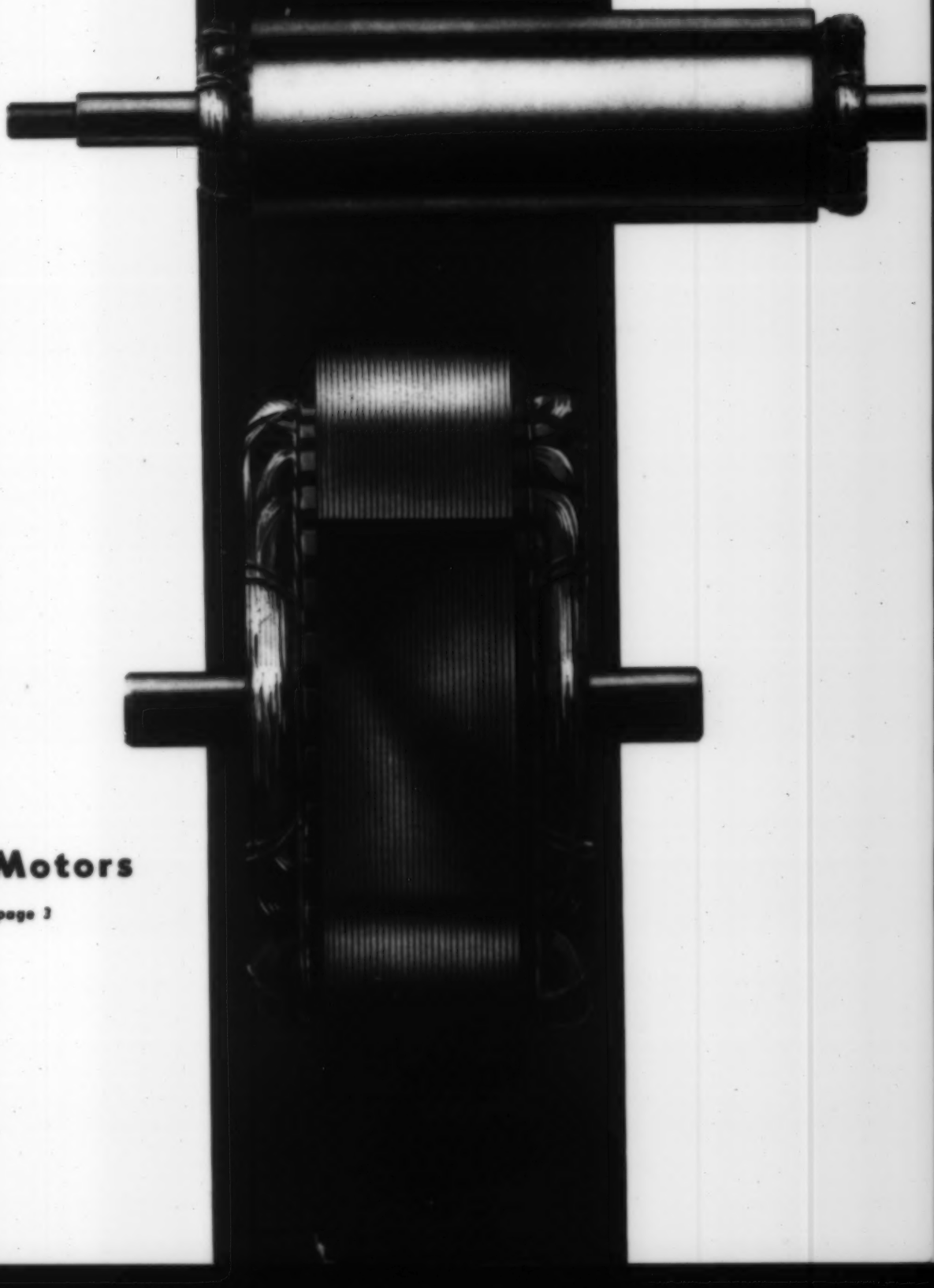

Special Motors

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NOVEMBER 1955
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Over the Board

Introducing a New Editor

This month, a new editor adorns our masthead on Page 3. He is Spencer R. Griffith, and his picture is on Page 53. Spence comes to MACHINE DESIGN from Hamilton Watch Co. where he was engineering services supervisor in the research division, and previously a member of the watch design section. Earlier work included experience at Landis Machine Co. Spence is a graduate of Lehigh Univ. (B.S. in M.E.). During the war, he was a captain in the Ordnance Dept. at Aberdeen Proving Ground. He is a member of American Ordnance Assn. Spence has also been active in community service work.

Words Wanted

We understand that the Army Ordnance Corps is preparing an extensive design manual for ordnance design engineers. The project will take, so we hear, about five years, and the complete work will contain some 18,000 pages. According to our calculations, this is equivalent to about 5,000,000 words.

With this many words to play with, the people in charge have foresightedly contracted with Western Reserve University to work out terminology and nomenclature problems. And Allen Kent of WRU has, in turn, asked us if any of our readers can supply formal or informal glossaries, collections of terminologies, or specialized dictionaries in fields of interest to ordnance work. If you can help Mr. Kent in his search for words, write him at: Center for Documentation and Communication Research, School of Library Science, Western Reserve Univ., Cleveland 6, O.

New Models

Continuing a trend of the past several years, 1956 model automobiles will be sleeker and easier to handle. Not to be outdone, we on MACHINE DESIGN are tying right into the trend. In 1956, we will produce a sleeker, easier-to-handle magazine in a new format.

The biggest change will be in our frequency of publication. In 1956, MACHINE DESIGN will be issued every other week instead of monthly. The magazine will be thinner and should take less time to read. However, total amount of engineering help provided during the year will be greater, because of increased frequency.

More about the new model MACHINE DESIGN will be found on the editorial page, Page 137. Or if you're interested in new automobiles, you can find the start of our 1956 review on Page 14.

This Month's Cover

Getting the right shape is always a problem—as anyone who has ever been on a diet can testify. In motors, a standard shape is not always best for the application. "Slimmed-down" or "rounded-out" shapes may be desired, as shown on George Farnsworth's cover. When to select a skinny or rotund motor is discussed in Robert Dobbin's article on Page 167, along with other factors involved in specifying special motors.

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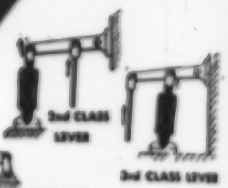

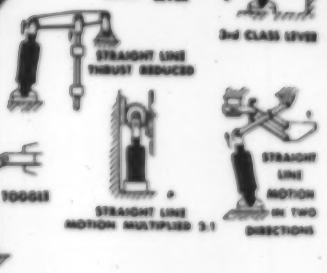

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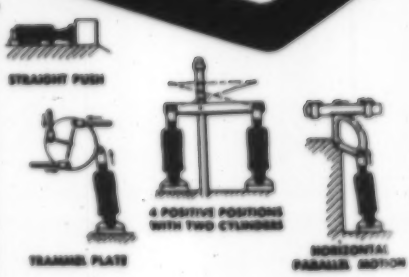

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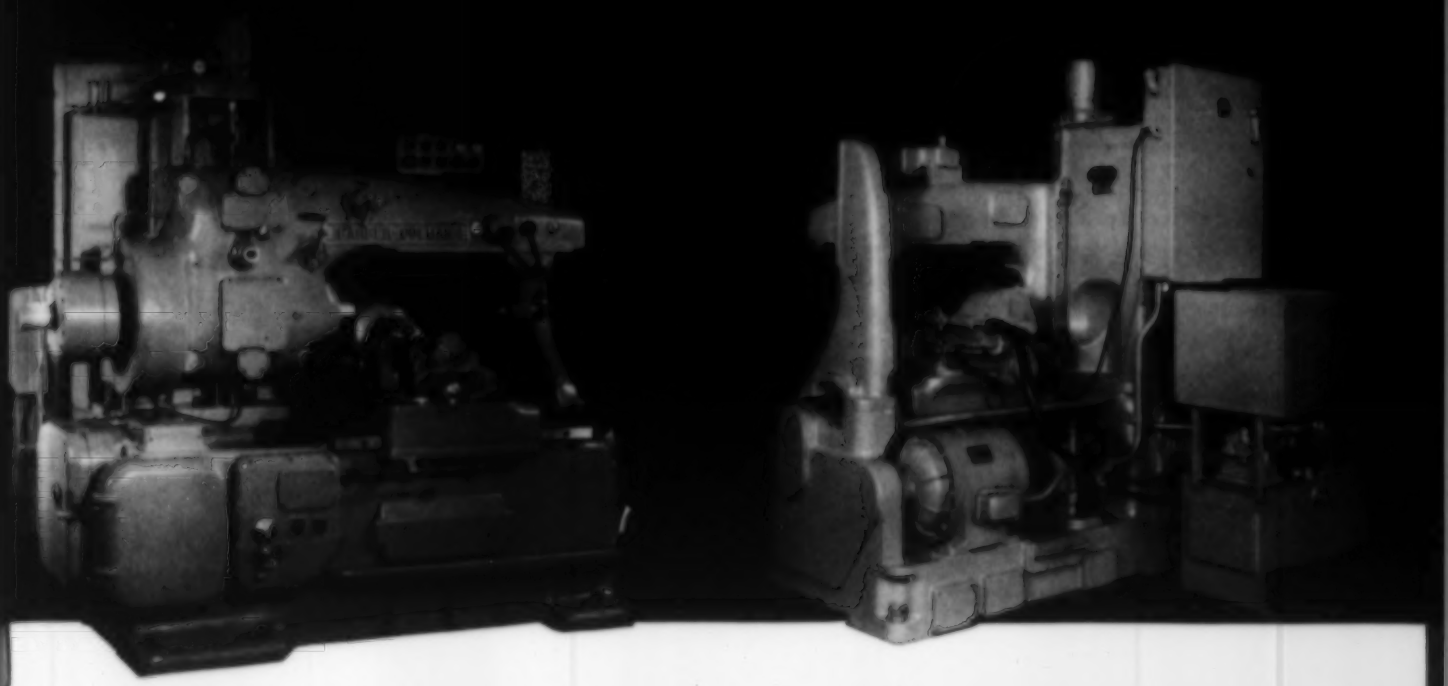

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Barber-Colman's new high-speed hobbing machine may be totally different from the machines you build. But the machine design problems they encountered in developing this machine could very well be your problems. Among the problems encountered was that of feed. To solve this problem, Barber-Colman selected Oilgear Fluid Power Feeds. These feeds give them the infinitely variable output to provide a hobbing feed range of .020" to 1" per minute. In addition, they provide a far more constant hobbing feed despite changes in load or system temperatures. They also provide cushioned, positive, precise, fast-acting electro-hydraulic control of feed, rapid traverse, and stop through automatic switches. Finally, they provide power for operating ten auxiliary cylinders and three valves. One Oilgear type AX-311 Pump supplies fluid power for the entire machine.

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TOMORROW: You dictate! The machine types and hustles your letters to the mail. Electronics does it all.

TODAY: In dictating instruments, New Departure ball bearings contribute to compactness of design and operating efficiency. They hold moving parts in alignment—reduce wear—require no upkeep.

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BALL BEARINGS

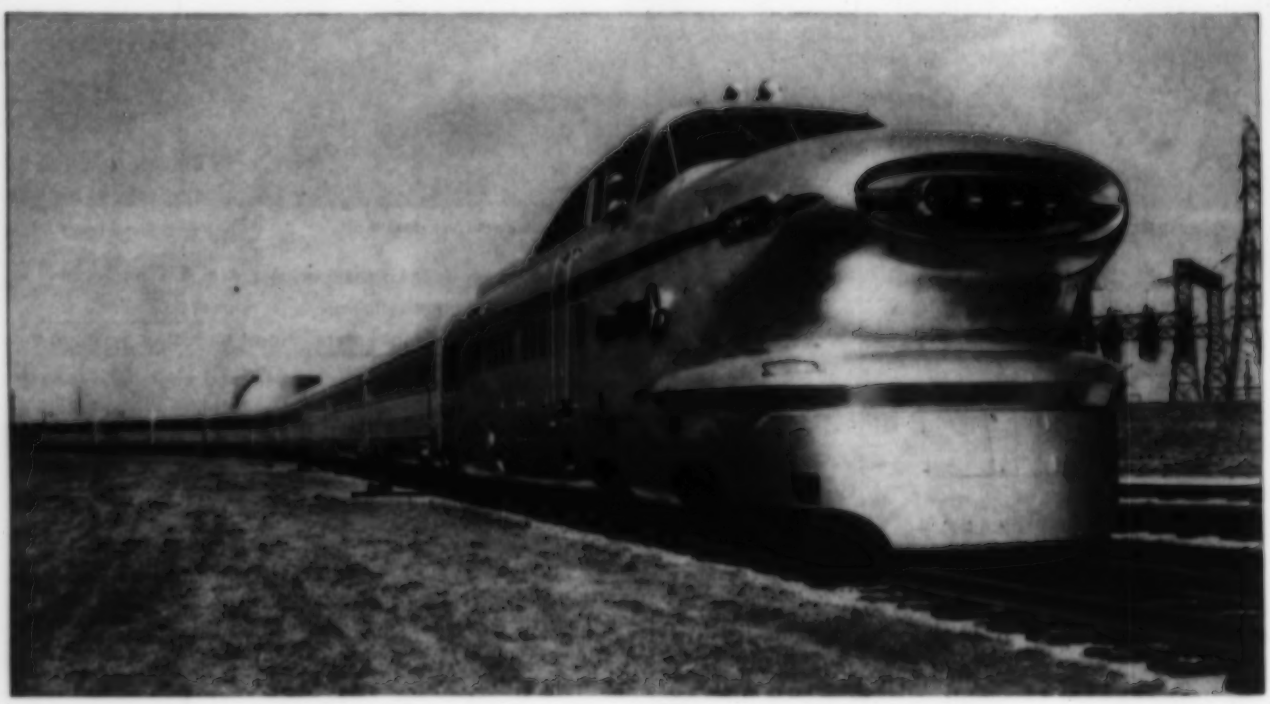
NOTHING ROLLS LIKE A BALL

Engineering News Roundup

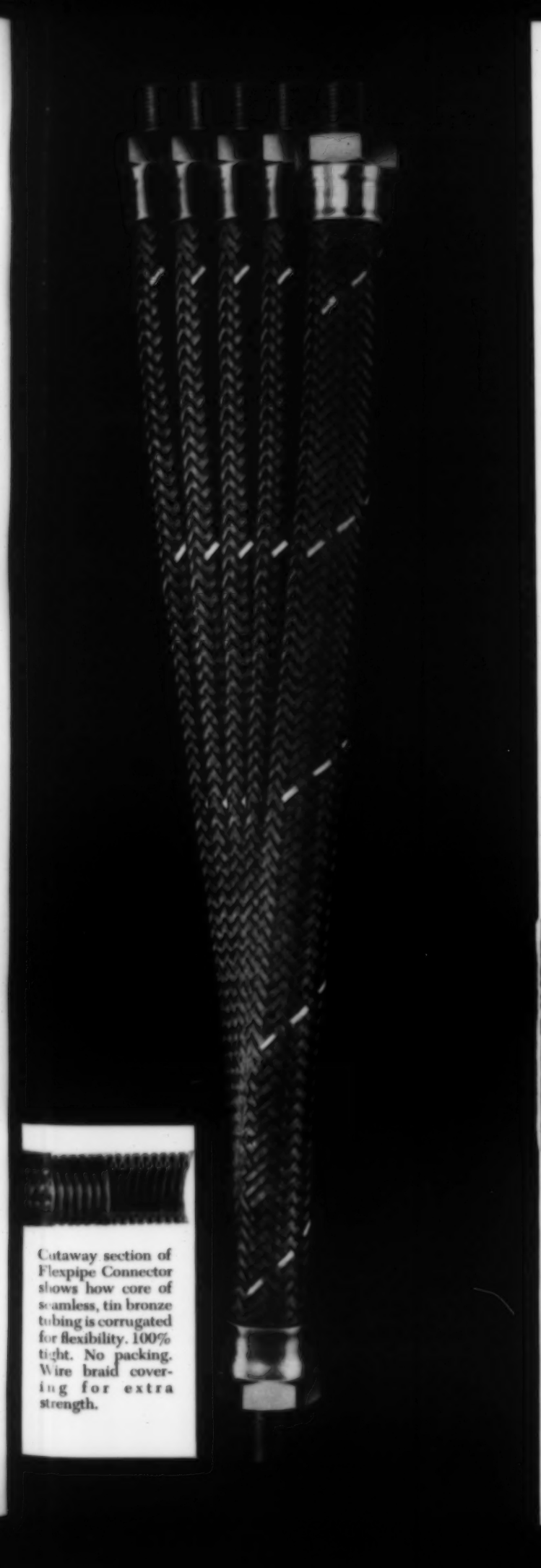
Standards Engineers Honor Senator Flanders, Others

HARTFORD, CONN.—Senator Ralph E. Flanders of Vermont was one of five men honored by the Standards Engineers Society at its Fourth Annual Convention at Hartford, Conn., September 29 to October 1. Senator Flanders was honored "in recognition of his outstanding contributions in government and industry". These included development of standard screw threads, making possible greater interchangeability, and encouragement of unified screw threads by the United States, the United Kingdom, and Canada. Senator Flanders was awarded an honorary fellowship in the Society.

Others were elected fellows of the society and honored "by reason of unusual professional distinction" in their respective standards fields. They were: Roger E. Gay, director of cataloging, standardization and inspection, Office of the Assistant Secretary of Defense (Supply and Logistics); Dr. Walter R. G. Baker, vice-president and general manager, Electronics Div., General Electric Co.; Harold R. Terhune, manager, Standards Dept., Federal Telecommunications Laboratories; Stanley Zwerling, assistant chief, Tests and Approvals Div., Armed Services Electro-Standards Agency.



AEROTRAIN, as this streamliner is called, is the first American-built complete lightweight passenger train. Developed by Electro-Motive Div. of General Motors, the 10-coach, 400-passenger train was exhibited at the recent General Motors Powerama. General design is patterned after intercity busses with baggage compartments on the outside. Conventional steel springing has been replaced by a suspension system using compressed air in rubber bellows. Weight of the coaches is 50 per cent less than a conventional coach carrying the same number of passengers



Cutaway section of Flexpipe Connector shows how core of seamless, tin bronze tubing is corrugated for flexibility. 100% tight. No packing. Wire braid covering for extra strength.

NOW... a new, standard flexible connector to save the cost of special design

FLEXPIPE* permits travel... absorbs vibration ...connects misaligned ports in pipe lines

Here's a new, *standard* tin bronze flexible connector you can use to convey air, gas, oil, steam or water. Flexpipe Connectors have standard plated brass pipe fittings at each end. They permit travel, flex with motion, and dampen vibration. They save time and materials by taking the place of rigid connections made up on the job with elbows, couplings and short runs of pipe. When intermittent travel occurs, Flexpipe Connectors move with the pipe, relieving stresses which shorten the life of rigid connections.

Flexpipe Connectors are designed for wet heating systems, and for trouble spots in commercial and industrial piping. Sizes, lengths, part numbers and operating pressures are given in the table below.

I.D.	Max. Offset each side of C/L (intermittent travel)	Over-all Length Inches	Part Numbers	Max. Working Pressure at Room Temp. PSI	Max. Working Pressure at Max. Temp. (350°F) PSI
¼	½ 1¼	8 16	¼ M-10 ¼ M-20	1200	850
⅜	½ 1¼	9 18	⅜ M-10 ⅜ M-20	1000	700
½	½ 1¼	10 20	½ M-10 ½ M-20	750	525
¾	½ 1¼	11 22	¾ M-10 ¾ M-20	600	425
1	½ 1¼	12 24	1 M-10 1 M-20	550	375
1¼	½ 1¼	13 26	1¼ M-10 1¼ M-20	300	200
1½	½ 1¼	14 28	1½ M-10 1½ M-20	275	175
2	½	18	2 M-10	200	125

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55204 (Rev.) *Trade Mark

...connects misaligned condensate drains

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Rounding Up the 1956 Automobiles

THE PAST several years' trend to higher horsepower is continued in the 1956 automobiles. Auto makers say the purpose of this power is to improve the performance of models equipped with automatic transmissions. Added power has been supplied either in newly-designed engines or by added carburetion to existing motors. The new engines generally feature shorter strokes and higher compression ratios.

To handle increased demands from the bigger power plants and from new accessories, 12-volt systems are standard in most lines. Automatic transmissions too are standard equipment on most cars.

Rider safety is emphasized on the 1956 models. Details featured are steering wheels with shorter hubs, padded dashboards and improved door latches.

An increased number of color combinations are available in 1956 lines. Optional accessories receiving increased emphasis include air conditioning and record players.

PLYMOUTH

Plymouth features a new engine for 1956. It has a 277 cu in. displacement and an 8 to 1 compression ratio. Other major innovations include pushbutton drive selector for Plymouth's PowerFlite automatic transmission, new safety door latches to keep doors closed even under severe impact, and new 12-volt

electrical system. Plymouth also offers safety belts anchored to the frame.

Optional power devices, in addition to pushbutton PowerFlite transmission, include full-time coaxial power steering, improved power brakes, pushbutton power front-seat adjustment and pushbutton power window regulators.

Engine Specifications

	PowerFlow Six	Hy-Fire V-8	
Type	L-head, In-Line	OHV, Vee	OHV, Vee
No. cyls	6	8	8
Bore & stroke (in.)	3.25 x 4.63	3.63 x 3.256	3.75 x 3.13
Displ. (in.^{3})	230	270	277
Comp. ratio	7.6 to 1	8 to 1	8 to 1
Bhp, max	131 @ 3600*	180 @ 4400	200 @ 4400*
Torque, max (lb-ft)	203 @ 2000*	272 @ 2400	285 @ 2400*

*With power package

Size and Weight

Wheelbase (in.)	115
Length (in.)	204.8
Width (in.)	74.6
Height (in.)	60.9
Weight (lb) (unofficial)	3307

The 1956 models are an inch longer than their predecessors. Standard sedans have an inch more headroom in front, and almost an inch more headroom in the rear.

BUICK

The new Buick line comes in four series, with 18 body styles mounted on two wheelbases. Dynaflow has been made standard equipment on all but the Special series. The 322 cu in. engine, previously used only on the Roadmaster, Super and Century, has been extended to the Special series.

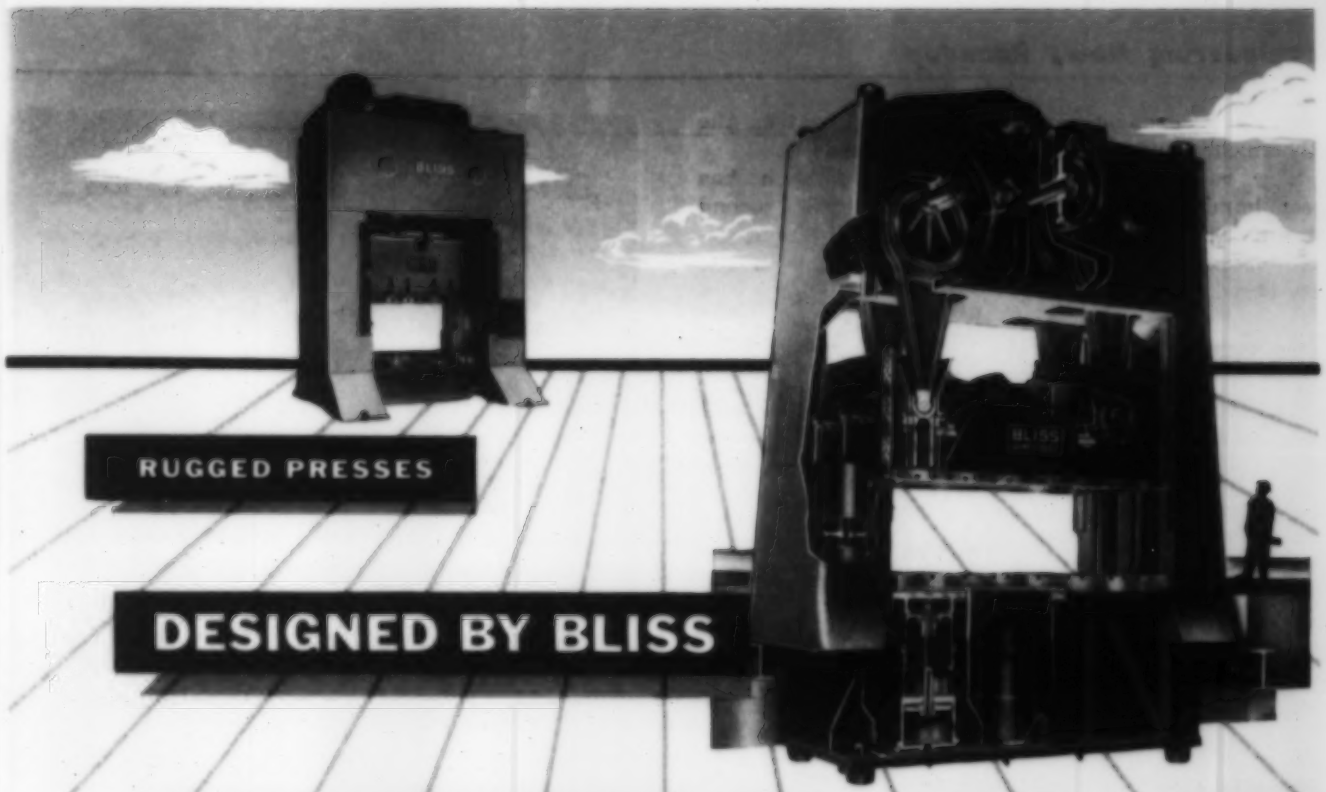
Engine Specifications

	Special	Super
Type	Vee	Vee
No. cyls	8	8
Bore & stroke (in.)	4.00 x 3.20	4.00 x 3.20
Displ. (in.^{3})	322	322
Comp. ratio	8.9 to 1	9.5 to 1
Bhp, max	220	255
Torque, max (lb-ft)	319 @ 2400	341 @ 3200

Size and Weight

	Series 40 and 60	Series 50 and 70
Wheelbase (in.)	122	127
Length (in.)	206.7	216.0
Width (in.)	76.2	80.0
Height (in.)	60.6	62.7
Weight (lb)	3807	4278

Safety features built into the 1956 Buicks include a foam-rubber pad atop the instrument panel, seat belts, improved power brakes, and improved accelera



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Bliss "packaged presses," built to JIC

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Pressurized Trabon lubrication circles every Bliss press with a moving ribbon of oil. Each bearing is lubricated at predetermined intervals. Automatic "Meterflo" action keeps an exact amount of filtered oil in continuous circulation.

"Meterflo" is foolproof . . . Hi-Lo pressure switch short-shifts oil supply failure or broken lines, automatically switching off the machine when wide pressure differential develops . . . a Trabon *exclusive*. Sealed system provides positive insurance against burned out bearings . . . no oil waste . . . no product damage . . . reduced lubrication costs.

Whether your machines are automated or single purpose, big or small, TRABON has a centralized automatic lubrication system to fit your needs.

Write for details . . . *positive* automatic lubrication insurance for any number of bearings.

• Bliss' design eliminates torsional deflection of main pin, minimizes distortions due to overloads.

• New automatic lubricating system — a recirculating type which has proved foolproof in service. Positive piston displacement method automatically lubricates every bearing surface at predetermined intervals. Electrical interlocks shut down press if a single feeder fails.

• Cool-running high speed clutch — Bliss' combination pneumatic friction clutch and brake is extremely fast— only a fraction of an inch needed between full engage-

Trabon ENGINEERING CORPORATION

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tion. Dual exhausts are standard equipment on the Roadmaster and optional on all other models.

The variable pitch Dynaflow transmission has been improved for 1956 by the addition of a second stator. This stator provides greater torque multiplication, improving performance and takeoff in the low speed range.

IMPERIAL

The 1956 Imperials feature some restyling and increased length. To complement these improvements, the Imperials offer a new pushbutton drive selector,

new high-fidelity record player, transistor radio, aircraft-type instant gasoline heater, new vacuum-operated center-plane power brakes, and new door latches. Horsepower rating of this year's engine has been stepped up to 280.

For 1956, Imperial introduces a new four-door hardtop which features a full-sedan body. In order to provide a full-sized, fully-opening rear door window, the window is made in two sections.

Engine Specifications

Type	OHV, Vee
No. cyls	8
Bore & stroke (in.)	3.94 x 3.63
Displ. (in.³)	354
Comp. ratio	9.0 to 1
Bhp, max	280 @ 4600
Torque, max (lb-ft)	*

*Not available

Size and Weight

	Imperial	Crown Imperial
Wheelbase (in.)	133	149.5
Length (in.)	229.6	243.6
Width (in.)	78.8	79.1
Height (in.)	61	62.4
Weight (lb)	4565	....

FORD

New Fords will be build in four series and 18 body styles. They are available in 13 solid exterior colors, or 21 two-tone combinations.

Two Y-8 engines lead the power plant options. One develops 202 hp for use with Fordomatic. The other is rated at 200 hp for use with overdrive or standard transmission. Customline and Mainline Fords offer a Y-8 engine developing 176 hp for Fordomatic, or 173 hp for overdrive or conventional drive. The Ford I-block six, increased to 137 hp, is available on all models with all transmission types.

New door latches give added protection against the chance that doors may open under impact. A new

three-spoke Ford steering wheel with its center hub recessed 3⅛ inches below the wheel rim is designed to keep the drivers' chest from hitting the steering

Engine Specifications

	I-Six	Y-8	Thunderbird Y-8
Type	Ohv, In-Line	Ohv, Vee	Ohv, Vee
No. cyls	6	8	8
Bore & stroke (in.)	3.62 x 3.60	3.62 x 3.30	3.75 x 3.30
Displ. (in.³)	223	272	292
With auto. trans.			
Comp. ratio	8.0 to 1	8.4 to 1	8.4 to 1
Bhp, max	137 @ 4000	176 @ 4400	202 @ 4600
With conv. trans. or overdrive			
Comp. ratio	8.0 to 1	8.0 to 1	8.0 to 1
Bhp, max	137 @ 4000	173 @ 4400	200 @ 4600
Torque	*	*	*

*Not available

Size and Weight

Wheelbase (in.)		115.5
Length (in.):	Passenger cars	196.5
	Station wagons	197.6
Width (in.)		75.9
Height (in.):	Sedans	60.4
	Victoria	58.4
Weight (lb)		*

*Not available

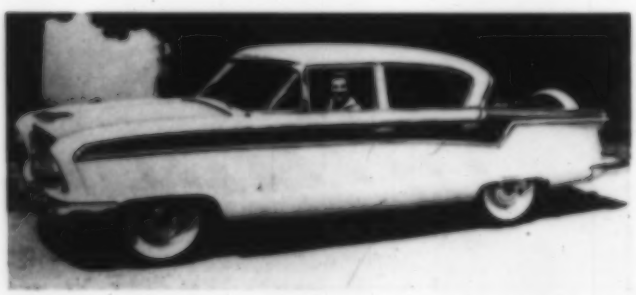
column in a crash. Seat belts and foam-rubber padding for instrument panels are optional safety equipment.

A 12-volt electrical system is standard on 1956 models, providing faster engine cranking and more capacity to handle an increased number of accessories.

NASH

Two new engines offering four horsepower ratings highlight the 1956 Nash line of Ambassador and Statesman models. Redesigned parking-running lights set off the front fenders. Three-tone paint combinations are available.

The new Ambassador Jetfire V-8 engine with Twin



From the collection of Lewis Winant, New Jersey Arms Collectors Club. Maker: Le Conte, Paris, France, 1758-1763. An 11-by-14 inch print of this illustration with part and lettering omitted is available free on request on company letterhead.

In producing this cam of sintered iron powder, Bound Brook competed directly with other forms of metal fabrication — and emerged victorious. Bound Brook's knowledge and experience with powder metallurgy combined the plus values of uniform density, consistent dimensional accuracy, good surface finish and high speed production to create a superior part at moderate cost. Whenever you are challenged with a metal-fabrication problem which is not easily solved by conventional metal-working methods why not call in your Bound Brook Man? There's no obligation for inquiring—and, in conjunction with your engineers, he could produce a winner!

9

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Ultramatic transmission develops 220 hp. A new 6-cylinder overhead-valve engine develops 130 hp. The Ambassador Super Jetfire 6 is rated at 135 horsepower and the optional LeMans Dual Jetfire 6 is increased to 145 horsepower.

All 1956 Nash models utilize a 12-volt electrical system. Synchromesh transmission is standard equipment on all six-cylinder Nash cars. Dual-Range Hydra-Matic is available on the same models.

Engine Specifications

	Statesman	Ambassador-6	Ambassador-8
Type	OHV, In-line	OHV, In-line	OHV, Vee
No. cyls	6	6	8
Bore & stroke (in.)	3⅛ x 4⅛	3⅛ x 4⅜	4 x 3⅛
Displ. (in.³)	195.6	252.6	352
Comp. ratio	7.44 to 1	7.6 to 1	9.55 to 1
Bhp, max	130 @ 4500	135 @ 3700*	220 @ 4600
Torque, max (lb-ft)	175 @ 1800	220 @ 1600	320 @ 2200-2500

*Optional 145 @ 4000

Size and Weight

	Statesman	Ambassador
Wheelbase (in.)	114¼	121¼
Length (in.)	202¼	209¼
Width (in.)	78	78
Height (in.)	61⅝	62⅛
Weight (lb)	3170*	3750*

*Shipping weight

LINCOLN

Lincoln for 1956 includes five models in the two series. Wheelbase has been increased from 123 to 126 inches and over all length from 215.6 inches to 222.8 inches. Height has been reduced to 60.2 in.

The Capri series includes a coupe and a four-door sedan, while the Premier line includes a coupe, a four-door sedan and a convertible. A range of 17

exterior solid colors, 35 two-tone colors and 29 interior color and trim combinations are available.

Lincoln has made both its new "in-line" power steering and its automatic transmission standard equipment on all cars. Premier models also have as standard equipment a new four-way power seat and power window lifts.

Safety features include a steering wheel with 3½ inches of "cushion" between its outer rim and the recessed top of the steering column, seat belts and new safety double-grip rotor-type door locks.

Engine Specifications

Type	OHV, Vee
No. cyls	8
Bore & stroke (in.)	4.00 x 3.66
Displ. (in.³)	368
Comp. ratio	9 to 1
Bhp, max	285 @ 4600
Torque, max. (lb-ft)	401 @ 2800

Size and Weight

Wheelbase (in.)	126
Length (in.)	222.8
Height (in.)	60.2
Width (in.)	79.9
Weight (lb) (unofficial)	4640

(To be continued in December)

New Process Makes Metals Out of Fibers

New Process Promises New Uses for Metals

CHICAGO, ILL.—A new metallurgical technique developed by Armour Research Foundation involves the use of a new starting raw material of short metal fibers. Use of the technique may result in bodies with novel properties, according to Armour researchers. For example, products having a wide range of porosities with high strength and toughness are possible.

Most of the operations in fiber metallurgy are the same as in powder metallurgy. The one fundamental difference is, of course, the use of fibers as the starting material. One of the outstanding properties of fiber metal bodies is that they lend themselves to felting processes.

In the felting process, the fibers are interlocked or felted in a flat sheet. After drying, they can be pressed to a higher density or a brazing material added to improve strength and ductility after suitable heat treatment.

Properties of fiber metal bodies can be adjusted by controlling the methods of manufacture. One such control may be in the selection of the wire diameter and length.

Filter materials are one of the fields of potential use of fiber metallurgy products. Another possible application is in a deicing system for aircraft. Here porous metals of high strength are used to distribute the deicing compound uniformly over the wing edge. Cooling of jet engine compounds is another suggested application.

New research center is to be constructed in Des Plaines, Ill. by **Borg-Warner Corp.** The new laboratory will contain facilities for metallurgical, electronic, electrical, chemical, acoustical, hydraulic, applied mechanical, physics and nuclear research. A complete machine and model shop, a computation center and technical reference library will also be part of the facilities.

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There's a growing preference for magnesium tooling plate—and good reason, too! It's lighter in weight, easier to machine, and lower priced than most commonly used tooling materials.

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Magnesium plate in all sizes is rolled for greater accuracy. Dimensional stability, too, is assured by stress relief through oven flattening.

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you can depend on DOW MAGNESIUM DOW

Shockproof Electric Furnace Uses Low-Voltage Elements

Corrugated Sheet Provides Large Heating Surface

CHICAGO, ILL.—Corrugated sheets of nickel-chromium make up the heating elements of a newly developed electric furnace. Developed by Lindberg Engineering Co., the new type heating elements are energized by an extremely low voltage. This voltage, reported to be in the neighborhood of 6 to 10 volts, is low enough so that accidental contact with the elements will not result in electrocution. Current requirements of the furnace, however, are about 20 times higher than those of conventional electric furnaces.

Called Corrtherm, the corrugated elements are hung from hooks extending through the roof of the furnace. Installation and replacement is relatively simple. Other hooks or supports are not required. When hung, the elements cover the entire walls of the furnace.

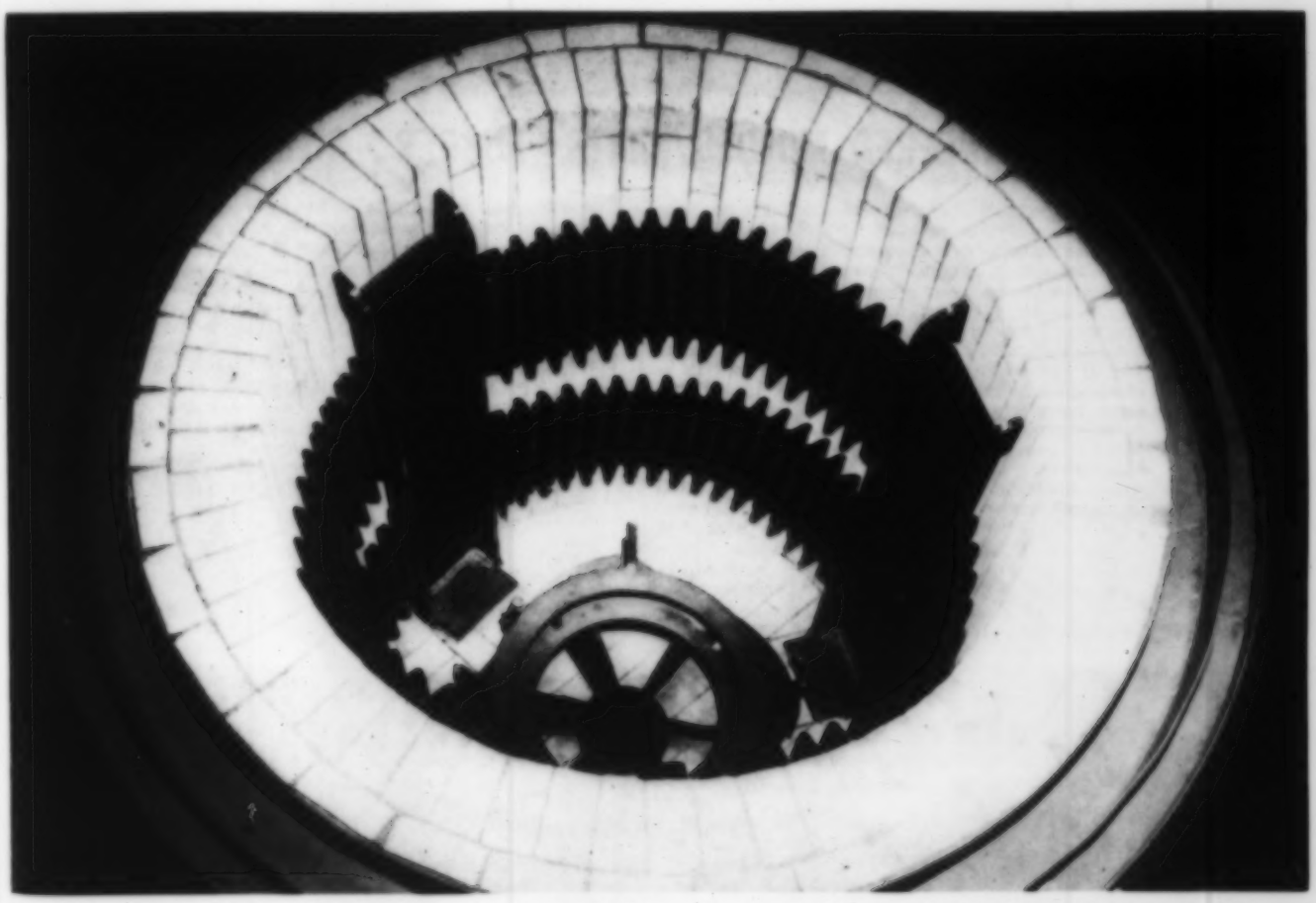
In forced-convection furnaces, where fans force hot gases through the charge, the elements act as directional baffles. In very large furnaces, the elements are not only hung adjacent to the walls but can be suspended into the heating chamber itself. On multiple-row pusher furnaces, the elements may be suspended between rows to provide more uniform heat. If desired, different temperatures at different locations may be provided by proper control.

Long life is a result of the relatively low surface temperatures. An oxide coating forms on the surface to confine the current to the elements even when covered with soot. In addition, a high-temperature enamel is fired on the elements.

Suitable transformers were also designed by Lindberg to provide the extremely high current required. The secondary of these transformers is one turn of heavy aluminum bus bar that connects directly to the elements. Because of the extremely low operating voltage, outside electrical connections need not be insulated.

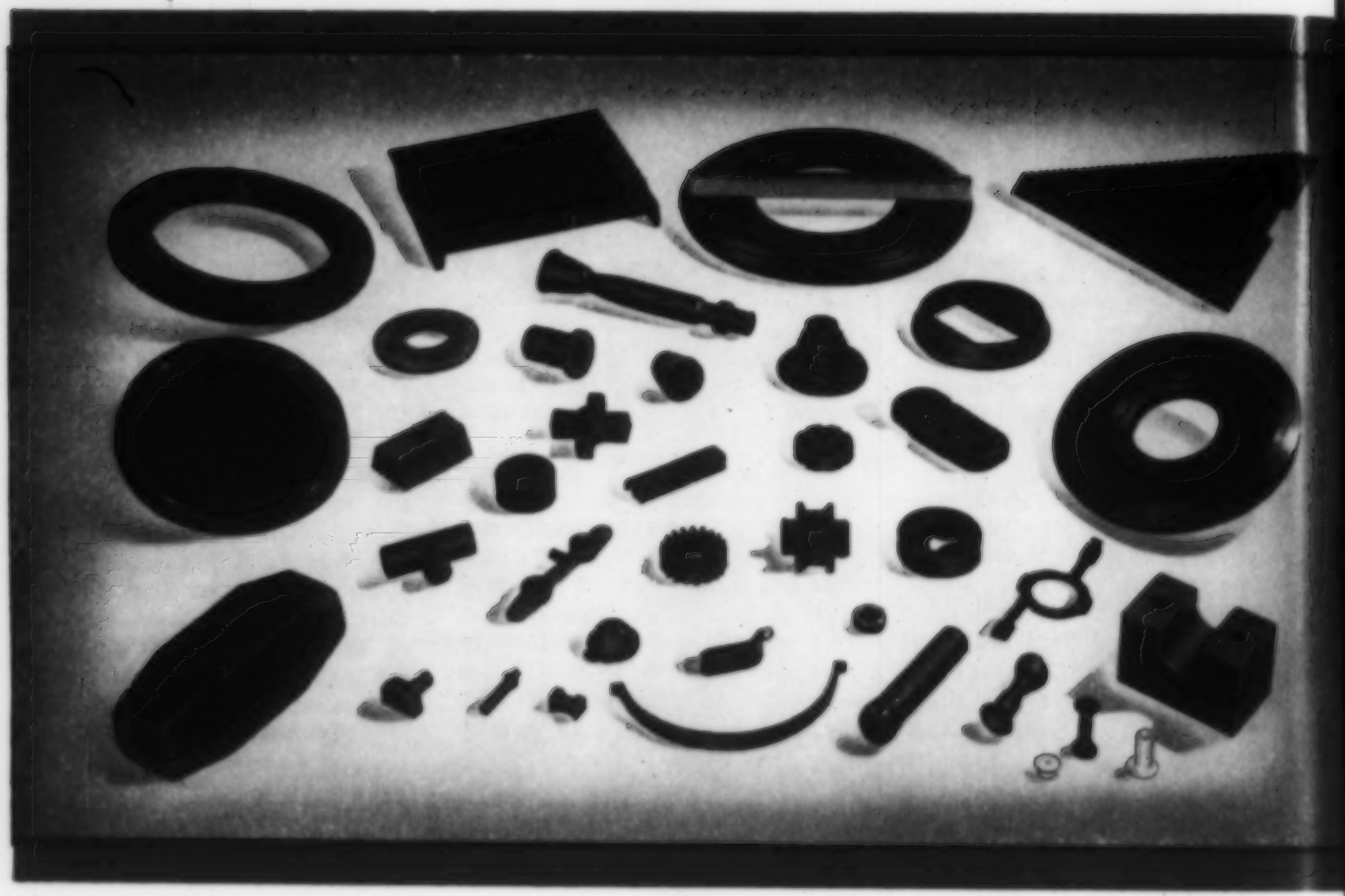
(*Continued on Page* 24)

A small electric furnace showing a typical installation of Corrtherm low-voltage heating elements. No short or shock hazard exists



New low-voltage heating elements in a pit-type vertical carburizing furnace. These corrugated nickel-chromium sheets were developed by Lindberg Engineering Co. and operate at extremely low voltages

CALL ON R/M ENGINEERING SERVICE



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R/M engineers can help you solve product problems with precision-made molded parts of natural or oil-proof synthetic rubber, silicone or nylon. R/M molded parts are custom-engineered to meet your particular requirements—to assure long life and trouble-free service under temperature, atmospheric, or other operating conditions. Specialists in the application of molded parts and components, R/M engineers assist you in determining the best design and material to meet new requirements . . . or to overcome troublesome conditions or higher costs caused by other materials you are now using.

Where your needs dictate, they will develop molded parts of natural or synthetic rubber. If silicone or nylon can do your job better, R/M will custom-engineer the exact parts you need to improve product performance, prolong product life or reduce cost. Backed by more than 60 years research and experience in the manufacture of molded and industrial rubber products, R/M molded parts are produced by skilled personnel working with the finest in laboratory testing facilities, under exacting quality control, and with modern mass-production methods. R/M offers you this same advanced engineering service with cut and extruded parts custom-made to your special order. Whatever your requirements, you can count on R/M for savings in design time and costs . . . and dependable deliveries.

A new, illustrated folder describes the unusual advantages of R/M Custom Molded Nylon Parts. Also, the R/M "Exclusive Features" book describes engineering advances in rubber hose, transmission and conveyor belts, V-Belts and R/M's new concept in power transmission, the Poly-V® Drive. Ask your R/M representative about Manhattan Rubber Division's Specialized Engineering Service for help with your rubber and nylon problems.

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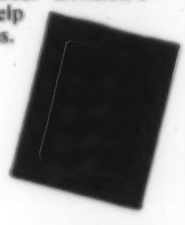

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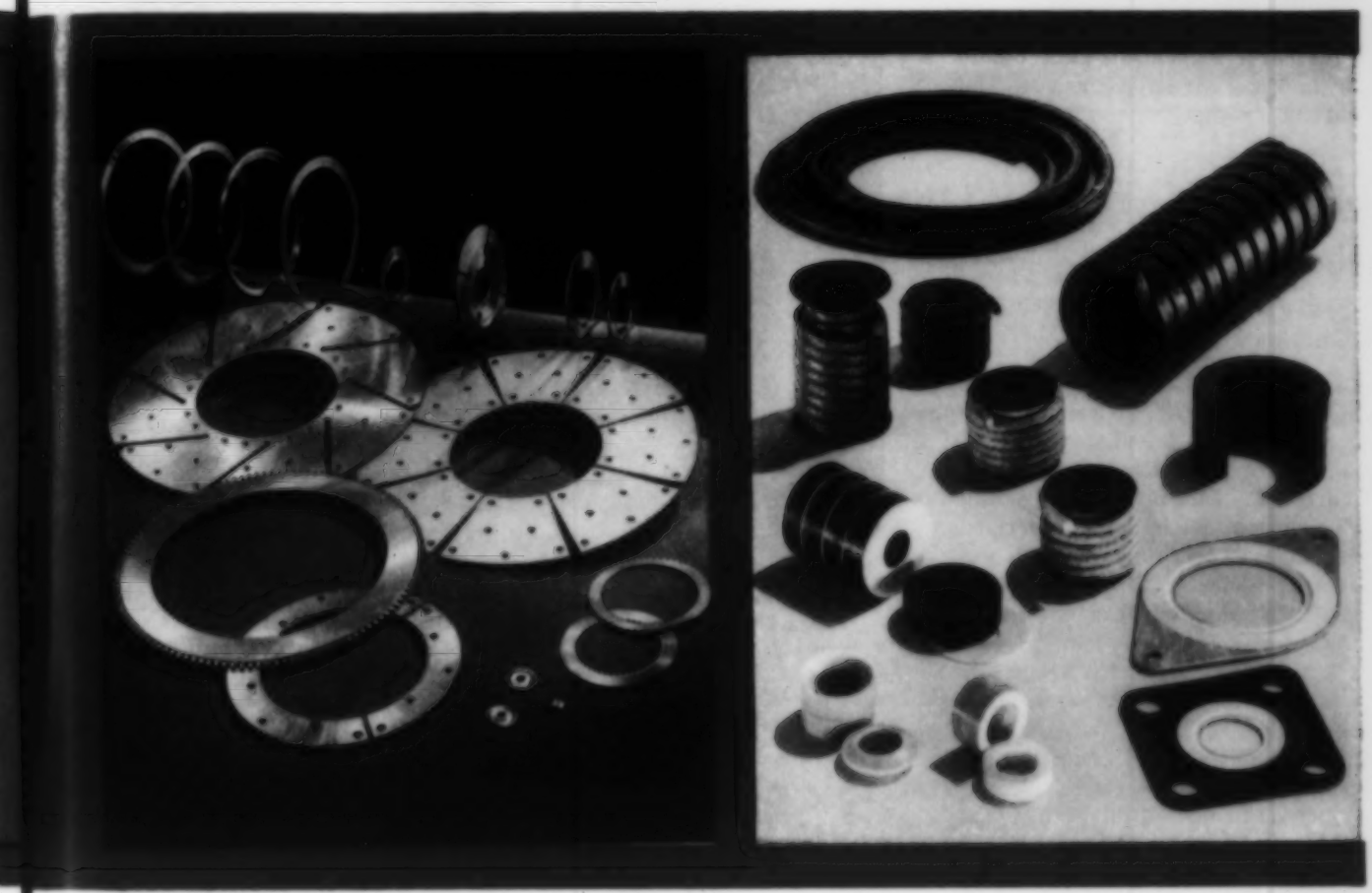

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Have a friction problem where high temperatures or close tolerances are factors? R/M Sintered Metal Friction Parts may be your answer. Under such severe conditions, R/M Sintered Metals will perform without appreciable increase in wear rate because of their high thermal conductivity and absence of destructible bond. Remember, unlike most manufacturers, R/M works with all kinds of friction materials. So whatever your friction requirements, you can be sure of completely unbiased advice when you consult Raybestos-Manhattan.

Write for your copy of R/M Bulletin No. 500. It's loaded with practical design and engineering data on all R/M friction materials.

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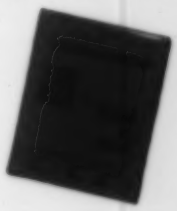

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Asbestos Textiles

Teflon Tape, Packings, Sheets, Rods, Tubes

Engineered Molded Rubber and Plastics

R M

(*Continued from Page* 21)

Principal use of furnaces using Corrtherm elements is expected to be in the field of carburizing and carbonitriding.

Welded Design Awards Announced

Best Developments in Machine Tools Chosen

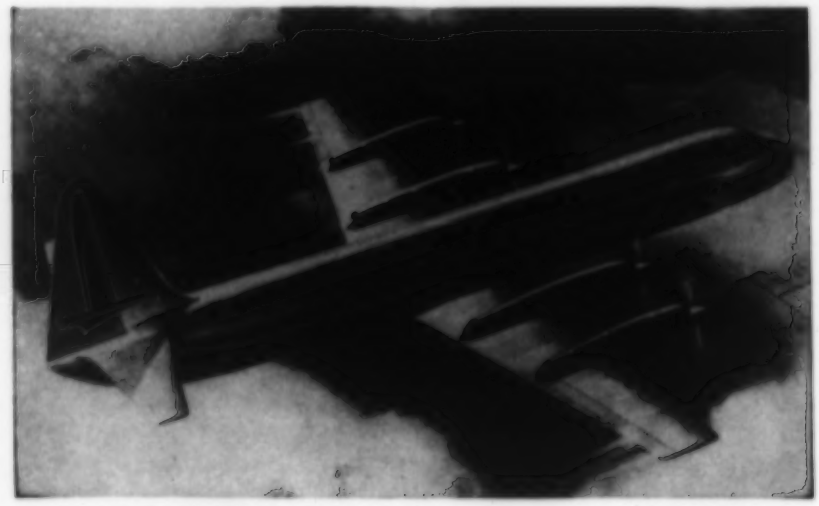
CLEVELAND, O.—Three engineers shared a $3000 first prize in the recent $12,000 Machine Tool Design Award Program sponsored by James F. Lincoln Arc Welding Foundation. Their paper described development work on vibration and rigidity undertaken in designing a new internal grinding machine with welded steel construction.

One of the first prize winners is Dr. Max Kronenberg, consulting engineer. Paul Maker, research engineer, and Edward Dix, project engineer, both with Bryant Chucking Grinder Co., shared the award with Dr. Kronenberg.

Second award was shared by Leonard McDermott, foreman, and Richard Fleury, stylist for the Brown and Sharpe Mfg. Co. These men wrote a paper describing redesign of a grinder base using welded fabrication techniques.

George Kasselmann, design engineer with R. K. LeBlond Machine Tool Co., received the third award. His paper described a 36-foot long template carrier rail of a roll turning lathe. Rigidity was increased by welding so that straightness tolerances were maintained even though weight was reduced more than 50 per cent.

Fourth award went to Alex Durand of Falk Corp. and fifth award to William Morgan of Clearing Machine Corp.



FIRST TURBOPROP airliner to be produced in U. S. (*Machine Design*, August, 1955, Page 12) is expected to go into commercial operation in 1958. Top speed is expected to be about 450 mph with a 2000 mile range. Called the Electra, the new transports are being designed and built by Lockheed Aircraft Corp. From 66 to 91 passengers may be carried

TRACKMOBILE shown here is a combination tractor and switch engine. Powered by a 100-hp V-8 engine, the Whiting Corp. machine is capable of 12,815 lb drawbar pull at 2.39 mph on rails. Top speed on rails is 15.2 mph pulling 2018 lb. On the road it will pull 3500 lb at 3.55 mph in first gear. In high it will travel 22.62 mph and can pull 1320 lb. Conversion from rail to road takes only 90 seconds. All controls, including those for positioning, raising and lowering the wheels, and coupling and uncoupling, are located in the cab. Sanders are built in for use with the rail wheels. Both automobile headlights and locomotive running lights are provided

HOWELL MOTOR BRIEFS

Quick facts for those who design-in and specify electric motors

Disc Motors . . . Space Savers Unequalled!

Here's the way to reduce the space occupied by a motor and still get performance characteristics equivalent to those of a conventionally designed motor. Depending upon horsepower, Howell Disc motors will effect length reductions of between 42 and 50 percent, with only a very slight increase in overall diameter.

This drastic space saving results from flattening the end plates and recessing the bearings into the motor. Howell is one of the few manufacturers who furnish disc motors (sometimes called "pancake" or "wafer-type") as a standard item.

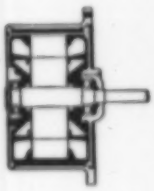


Fig. A

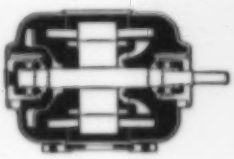


Fig. B

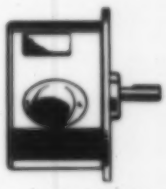
Fig. A, showing the Howell disc motor design, illustrates how the bearings are recessed into the rotor. Compare this with Fig. B, showing conventional motor construction. Both designs provide ample copper wire and lamination steel in the motor.

As compared to other disc motors having the rotor recessed into the stator, Howell's disc motor design has these advantages: (1) Effects a greater reduction in size; (2) Has no axial air gap to vary and cause motor "howl" or power loss, when bearings wear over an extended period; (3) Service, if ever needed, is simplified because of the conventional rotor and stator construction.

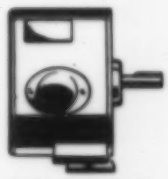
It's a tried and proved design — Howell Disc Motors have been used with excellent results on machine tools, punch presses, cranes and hoists, among many other applications . . . and new uses are being developed constantly. Because there are no ventilation ports in the end plate at the pulley end of an open-type disc motor, it's ideal for vertical, shaft-up mounting.

Howell can furnish all the electrical types available in conventional motors — multi-speed, high torque, high slip; single or polyphase; Class "B" or "H" insulation included. They're readily combined with the Howell friction brake to make an extremely compact and efficient type of brake motor.

They are offered as standard motors in Frame sizes 56 through 32, both in open and enclosed, fan-cooled constructions. Mountings: either NEMA "C" face end plates or foot-type as illustrated.



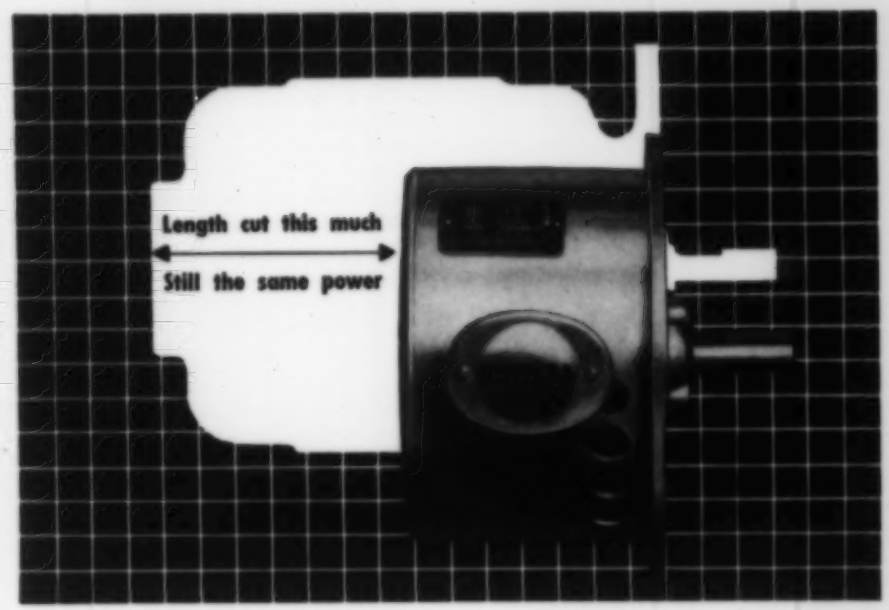
FLANGE MOUNTING



FOOT MOUNTING

Sizes range from ¼ to 20 h.p. at 1800 rpm, including intermittent hoist types.

Write for Bulletin DT-1



Howell's distinctive motor construction, as applied to the disc type motor, includes such features as these:

High-quality insulation. Seven different pieces of insulation for each slot cell. Complete insulation between top and bottom coils and between all phase groups. Lead wires brazed to coil ends and insulated with vinyl chloride plasticized fiberglass tubing.

Copper-clad rotor. Copper bars and end rings are welded or brazed together for unusual strength. High melting point of copper prevents damage from high temperatures caused by possible over-loads.

Expert craftsmansh'p. Rotors are ground to precision limits for exact concentricity and uniform air gap. They are dynamically balanced at rated speeds.

High-quality coil varnish. Entire stator is thoroughly impregnated twice with the finest phenolic resin-base varnish, twice baked for extra protection.

Leakproof oil seals. Provide dependable, dirt-free operation.

HOWELL Red Bond MOTORS

HOWELL MOTORS

HOWELL ELECTRIC MOTORS COMPANY, HOWELL, MICHIGAN

PRECISION-BUILT MOTORS FOR INDUSTRY SINCE 1915

S-l-i-d-i-n-g

CONTACTS & BRUSHES OF SILVER-GRAPHITE

. . . for minimum, more stable contact resistance . . . less radio noise interference . . . greater reliability

From servo mechanisms to radar antenna operating units, calculating machines, midget motors and dozens of other exacting applications, sliding contacts or brushes of Stackpole silver-graphite assure maximum contact efficiency and life at minimum cost. Lowest radio noise levels short of using costly noble metals are obtained by using these silver-graphite units against a silver ring. For ordinary uses, a copper ring or commutator will suffice.

Available in sizes from ⅛" diameter upward, they can be supplied with silver-soldered backs for easy spot welding or brazing directly to supporting springs or arms and with or without shunts. Contacting assemblies are thus greatly simplified. Units are supplied either separate or mounted to specifications. They are made of silver with almost any desired percentage of graphite. Standard grades range from 0% to 50% graphite.

STACKPOLE CARBON COMPANY

St. Marys, Pa.

STACKPOLE

Stackpole contact material types include SILVER-GRAPHITE • SILVER-LEAD OXIDE SILVER-NICKEL • SILVER-MOLYBDENUM • SILVER-TUNGSTEN • COPPER-GRAPHITE SILVER-COPPER-GRAPHITE • GOLD-GRAPHITE • SILVER-IRON OXIDE and many special grades.

News Roundup

Flame Cuts Nonferrous Metals

New Process Speeds Aluminum Fabricating

PHILADELPHIA, PA. — Nonferrous metals may be cut faster by using a gas-shielded arc process, according to a recent announcement by Linde Air Products Co. The company has developed a process by which cutting speed of nonferrous metals is increased, but the finished cut has a saw-like quality.

Similar to oxygen cutting for steel, the new Heliarc cutting process uses an argon-hydrogen mixture as the shielding atmosphere surrounding a tungsten electrode.

A high-temperature, concentrated arc stream melts and ejects the metal. The gas prevents oxidation of the cut face. Kerf edges of all cuts have square corners and no attached dross.

Typical cutting speeds are shown in the accompanying table. Cutting can be mechanized or manual in any position. Straight lines, circles, bevels or odd shapes may be cut.

Typical Heliarc Cutting Speeds

Thickness (in.)	Speed (ipm)	Power Supply (amp)	(v)	Gas Flow* (cfh)
¼	300	320	70	50
½	125	320	75	60
¾	75	320	77	70
1	50	320	80	70

*Gas used is an argon-hydrogen mixture

At present, the development of Heliarc cutting has been concentrated on aluminum fabrication applications. However, the company plans to investigate applications in the nonferrous field in general

Professional Engineers Guidance Consulting Service has been established by John D. Constance, 625 Hudson Terrace, Cliffside Park N. J. The service is designed to prepare candidates for engineers registration in any state.

New inorganic filler material known as Kanamite is being produced on a pilot plant operation by Ferro Corp. and is slated for

commercial production soon. Currently, initial production is being used in casting resins in certain classified electronic equipment, as a core filler in plastic dies, and as a strength additive in foamed plastics.

Kanamite is the trade mark for unicellular, spheridized clay particles fired at about 3000 F in a process developed several years ago by the Kanium Corp. in a research project conducted at the Armour Research Foundation. Widened uses are expected in plastic core materials for building panels, flotation materials, dies and many other places where inorganic lightweight fillers are desired. Very long range possibilities are in ceramic and lightweight concrete products.

"It's the low center of gravity that holds these light plastic cars on the road."

Ultrafine Flat Wire Smaller Than Human Hair

LANCASTER, PA.—Extremely fine flat wire, just announced, is smaller than a human hair. Held to very close tolerances of thickness, width and uniformity of cross section, the wire is now available commercially from the Allied Products Div. of Hamilton Watch Co.

Made by a process used for watch hairspring material, the wire can be as fine as 0.0007-in. thick by 0.003-in. wide. Tolerances can be ±0.00001-in. on thickness and 0.001-in. on width. Maximum thickness is 0.010-in., and maximum width is 0.019-in.

The wire is produced free from twist so that fabricated spiral springs lie flat, permitting easy assembly. Wire can be produced

AN IMPORTANT
NEW CATALOG
FOR YOUR
FILES!

WINSMITH, Inc., 16 Elton Street
Springville, (Erie County), N. Y.

Gentlemen: Please send me a copy of Catalog 155 on the new Series "C" Speed Reducers.

NAME TITLE
COMPANY
ADDRESS
CITY ZONE STATE

WINSMITH CATALOG 155
DESCRIBING THE NEW
"C" SERIES
SPEED REDUCERS

Between the covers of this new catalog, every design engineer and speed reducer user will find the answer to how they can select speed reducers of more compact dimensions to achieve required output.

With this newly designed "C" Series, Winsmith has succeeded in increasing horsepower and torque output, and increasing the ruggedness of the units *without increasing overall size*. In all, 108 models in single and double reduction are available within the range of .01 to 34 hp; in a ratio range of 5:1 to 4460:1 and in an output torque range of 142 in. lbs. to 34,767 in. lbs. The complete "C" Series plus a number of other popular models in the Winsmith line are catalogued for your working convenience.

Dimension drawings, parts list, shaft arrangements and table of weights are on facing pages for convenience in working. Opens flat on desk or drawing board.

Ratings are given in easy-to-read form . . arranged in sections so they can be located instantly.

Engineering "Handbook" Section is well illustrated and contains informative text material. Designed to help you solve application problems.

FOR YOUR COPY OF CATALOG 155 FILL IN AND MAIL THE COUPON TODAY!

WINSMITH
SPEED REDUCERS

WINSMITH, INC.
16 Elton Street
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. . . a single source for the most complete line of speed reducers within the range of 1/100 h.p. to 85 h.p. in ratios of 1.1:1 to 50,000:1

NEED RELAYS?

SPECIFY

AEMCO

and get more for your relay dollar!

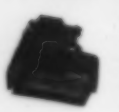
Pick the size you want . . . choose the features you need . . .

you'll find that an AEMCO relay will meet or exceed your specifications. Compact in design, dependable in performance, AEMCO relays are manufactured with extreme care —the choice of more than 100 top names in American industry—and here are the reasons why:

Lower cost—due to modern production techniques and fresh, new engineering ideas. All AEMCO products are designed with shortcuts and specific production economies in mind.

Top quality—based on more than 30 years experience. We'll work closely with your design engineers, and we'll do it without red tape or confusion.

Many standards—to choose from. AEMCO relays are available in a wide variety of spring and coil combinations, operating potentials, and contact ratings. Types include: open, can, plug-in base, hermetically sealed, midgets, dual-purpose, delayed make or break, circuit control, current, and potential relays.



Speedy prototype delivery—and quick tool up for production. Yes, at AEMCO we're selling service as well as design and manufacturing ability.

AEMCO

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61 STATE ST. • MANKATO, MINNESOTA

from most ferrous and nonferrous alloys except a few that are difficult to cold work.

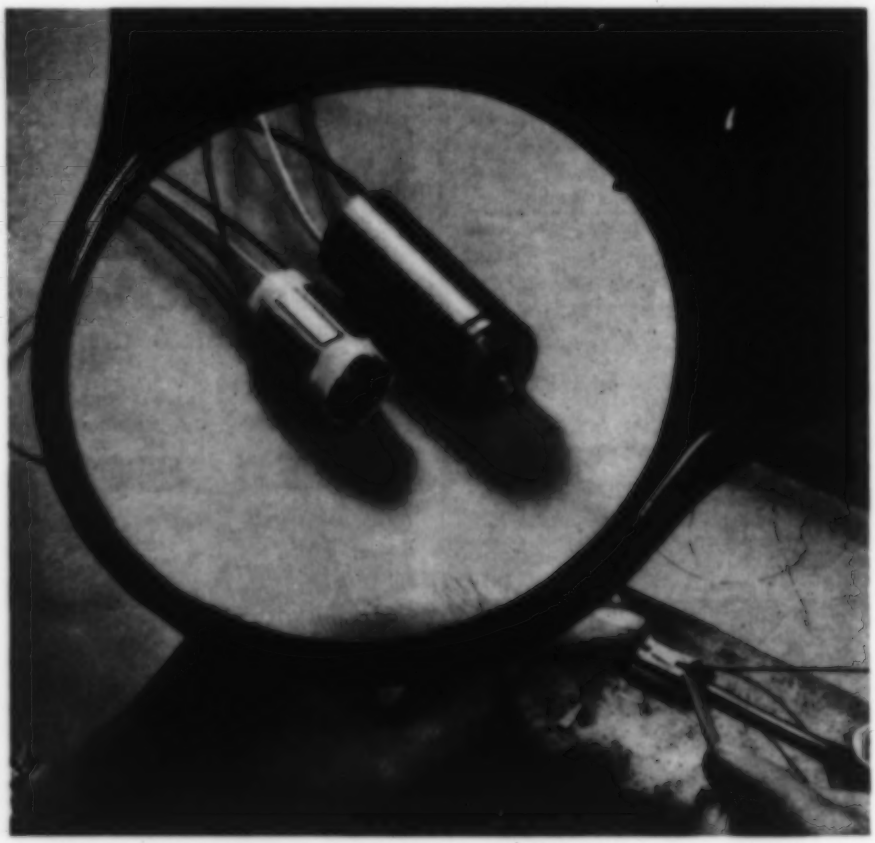
Possible applications for wire this fine are springs in precision timing elements, precision electrical and aneroid instruments and high-sensitivity electrical relays.

Midget Servo Motor Developed for Aircraft

SCHENECTADY, N. Y.—A two-phase servo motor developed by General Electric is believed to be the smallest currently used on aircraft. Originally designed for use in a gyrocompass unit, it may be adaptable to other uses, according to GE engineers.

Weight of the motor is only 1.2 oz. It measures 1.2 inches long and has a diameter of $\frac{5}{8}$-inch. Rated at 26 volts, the motor's no-load speed is 21,000 rpm.

Designed to withstand ambient temperatures from −55 to 90 C, the motor is said to give satisfactory performance up to 60,000 ft.



Smallest motor currently being used in aircraft is shown here. Two motors are shown in the magnifying glass in different stages of completion

Vacuum Melting Used In Investment Casting Process

New Furnace Promises More Investment Cast Alloys

NEW YORK, N. Y.—The first vacuum melting furnace designed specifically for the investment casting process has been put into operation on an experimental and pilot production basis by Austenal Laboratories, Microcast Division, at its Dover, N. J., plant.

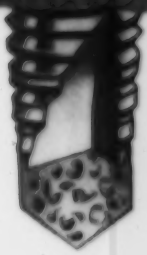
Introduction of vacuum melting to investment casting is expected to extend considerably the versatility of the process, permitting the use of a wider range of alloys and insuring greater strength and

Why SHAKEPROOF® THREAD-CUTTING SCREWS give a better fastening... faster!

Shakeproof Thread-Cutting Screws offer you immediate assembly savings.

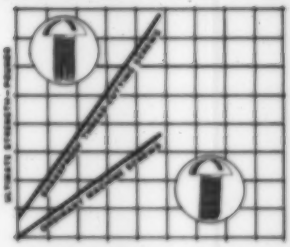
They cut their own threads, eliminate separate tapping operations completely.

This thread-cutting slot exposes a sharp, serrated cutting edge.

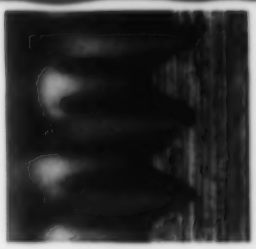


Shakeproof Thread-Cutting Screws actually work with true tapping action.

You get big savings. Just drill or punch hole drive—that's all! No tapping, no tapping tools!



These hardened screws provide greater strength . . . often permit use of smaller sizes.



Self-cut mating threads assure a tight, vibration resistant fit.

Type 1 Thread-Cutting Screws are specially designed for use in hard metals.

Type 23, with wider thread-cutting slot, is for use in metals and plastics.

Type 25, with spaced thread, is designed for use with plastic materials.

Eliminate costly taps and tapping . . . improve quality and cut costs at the same time.

Every screw is a cost saver when you specify Shakeproof Thread-Cutting Screws.

Free Sample Kit

Now . . . make your own tests! See for yourself how Shakeproof Thread-Cutting Screws can save money in your plant. Write for your free sample kit today!

SHAKEPROOF

"Fastening Headquarters"®

DIVISION OF ILLINOIS TOOL WORKS

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WORLD'S BROADEST LINE OF MASS-ASSEMBLY FASTENINGS

"you can service an EMSCO swivel joint without removal from line"

NO EXPENSIVE RETURN TO FACTORY FOR REPAIR

Within a few minutes you can inspect and service Emsco Ball Bearing Swivel Joints. Simply break the Emsco as you would a pipe union. Packing is then readily accessible and easily replaced if necessary. This is vitally important to the field man and reduces maintenance costs. With Emsco you can count on free easy turning and years of economical service life.

Emsco Swivel Fittings are manufactured in popular sizes for practically every type of service; from high vacuum to pressures of 15,000 psi, and from sub-zero temperatures to 750° F. Simply tell us your application and type of end connections required. When you buy a swivel joint, specify Emsco.

EMSCO

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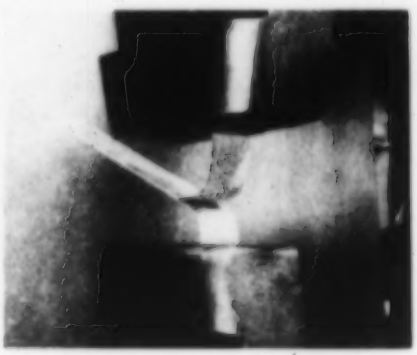
Box 2098, TERMINAL ANNEX
LOS ANGELES 54, CALIF.
Houston, Texas
Garland, Texas

ductility of alloys now being used.

Specifically, the melting of metals in a vacuum eliminates harmful gases, and undesirable oxides and slag compounds. Appearance of these elements in standard melting processes has limited the choice of alloys used in investment casting to those that are not affected, or affected only slightly, by these factors.

The investment casting process is used primarily to mass produce small precision parts in a wide range of alloys, ranging from the high-strength, high-temperature alloys, through the stainless steels, to the carbon and low-alloy steels.



PEEL TEST: This machine for testing metal bonding adhesives has been developed for Douglas Aircraft Co. Made by Baldwin-Lima-Hamilton Corp., the machine records total load vs crosshead motion as the specimen is being pulled apart

Big Machine On Campus Is World's Largest Tester

BETHLEHEM, PA. — The world's largest universal testing machine was dedicated at Lehigh University on October 14. Capable of applying loads in either tension or compression up to 5-million lb, the machine can handle vertical specimens up to 40 ft long. Beams or girders up to 100 ft long may be tested in bending at full capacity load of the machine. Weight with accessories is about 925,000.

Loads are applied hydraulically

by a movable cylinder on a stationary piston 54 inches in diameter mounted on the bottom of the base. Hydraulic pressure at maximum load is 2200 psi.

The cylinder carries two vertical screws through which loads are

New 5-million lb universal testing machine installed in the Fritz Engineering Laboratory at Lehigh University. Built by the Baldwin-Lima-Hamilton Corp., the machine towers 60 ft above the test floor and 16 ft below—a total of 76 ft. Specimens 40 ft high can be tested in compression or tension. The machine base will accommodate structures 100 ft long and nearly 10 ft wide

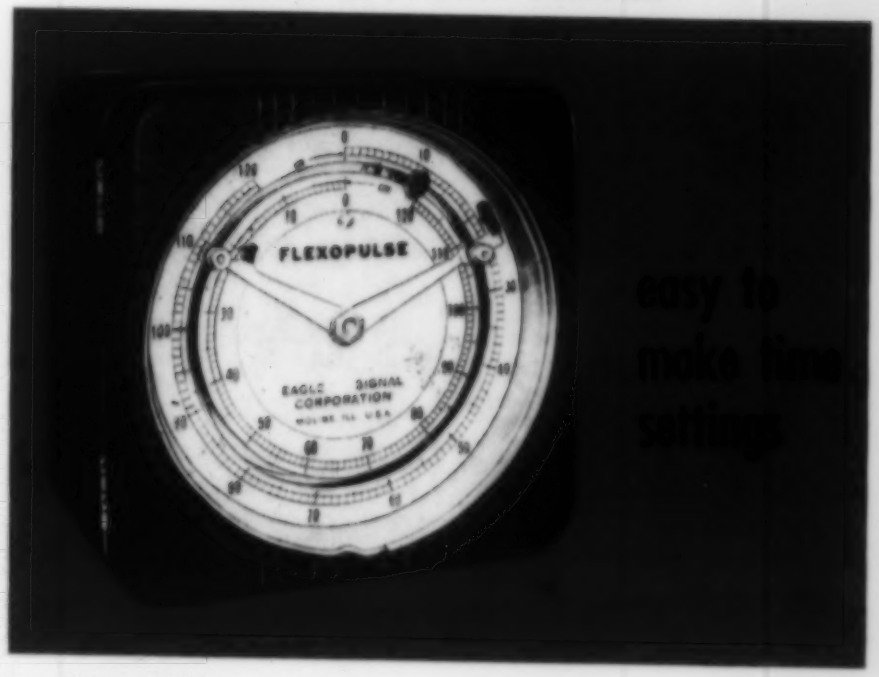
applied on test specimens. These screws, believed to be the largest ever made, are 62 ft long, 16 in. in diameter, and weigh nearly 45,000 lb each. They are in tension when loads are applied. A 75-hp electric motor rotates the screws to position the crossheads when preparing for a test.

The load-measuring system is hydraulic and completely independent of the loading system. It consists of a 56 inch-diam Emery cell mounted in the sensitive crosshead, and a null-balance Tate-Emery indicating system in the control console. Connection is

(*Continued on Page 36*)

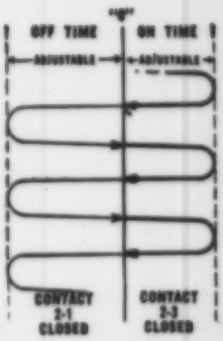
EAGLE FLEXOPULSE repeat cycle timer

WITH S.P.D.T. SWITCH



No gear change or resetting of cams required

This Flexopulse Repeat Cycle Timer is ideal for controlling processing machines requiring adjustable timed cycles. The "on" or "off" intervals are easily adjusted. Either can be adjusted without disturbing the setting of the other. Instead of resetting cams or changing gears, simply loosen two knurled nuts. Then set "on" and "off" periods by moving adjustable pointer. Tighten screws, and the job's done.



HAS CYCLE PROGRESS INDICATION:

A movable flag indicator passing over the time scale between adjustable arms, indicates portion of cycle elapsed in either of the s.p.d.t. positions. Switching operation takes place at zero.

Flexopulse is ideal for periodically operating valves to reverse the flow of liquids, for operating signals or for injecting chemicals. 120-second up to 20-hour dials are available. Synchronous motor powered. Send coupon today for free Bulletin 320.

FREE BULLETIN, MAIL COUPON

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Industrial Timers Division, Dept. MD-1155
MOLINE, ILLINOIS

Please send free Bulletin 320 with full data on Flexopulse Repeat Cycle Timer.

NAME AND TITLE

COMPANY

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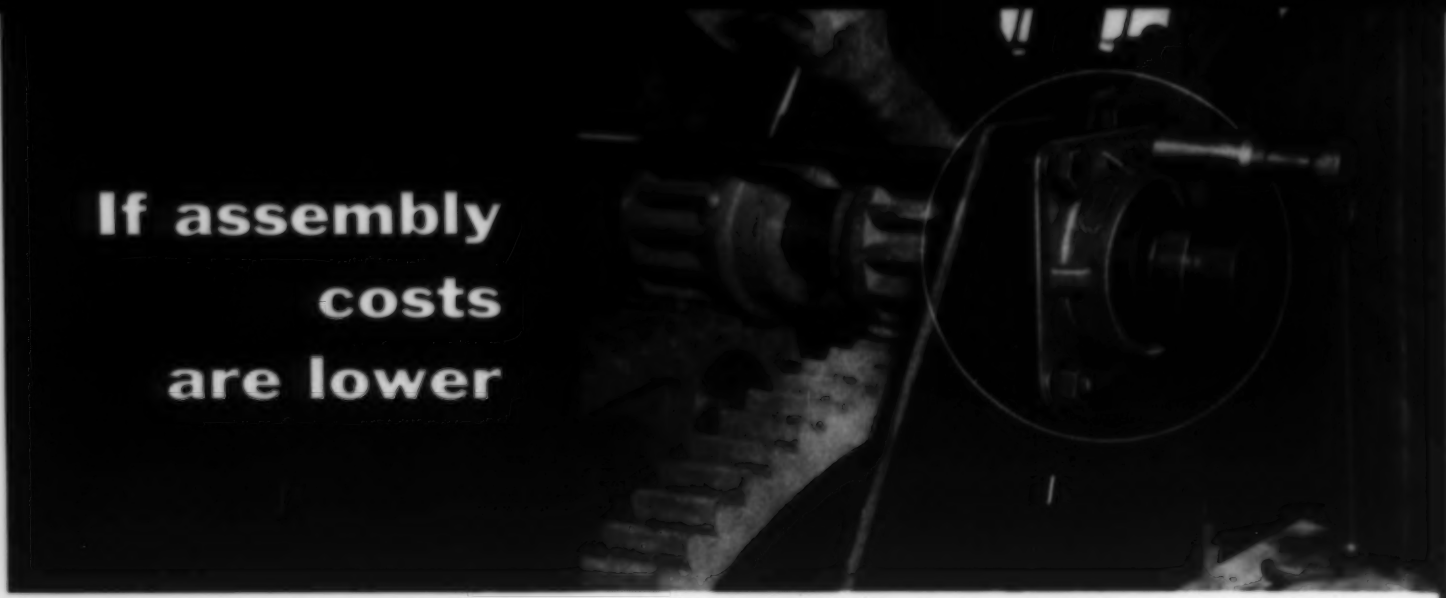


If assembly costs are lower

chances are

Fafnir has a bearing on it

Type LCJ Self-Aligning Ball Bearing Flange Cartridge equipped with Wide Inner Ring Mechanoseal Bearing and Self-Locking Collar. For shaft diam.: ½" to 3 15/16".

The installation of a Fafnir Ball Bearing Flange Cartridge on the pinion shaft illustrated is being made with a socket wrench. No complicated blue prints, no costly machining, no time-consuming fitting and adjusting of bearing. Assembly costs have been cut without cutting corners.

The use of a completely-housed ball bearing unit is only part of this cost-cutting operation. The *Fafnir Unit* offers additional cost savings. Its bearing inner ring is bored for a slip fit. The eccentric cam design of its inner ring and collar makes locking action positive with a twist of the wrist. No lock nuts or adapters are needed. No adjustments of any kind are necessary. The bearing can't be cramped or overloaded when mounting.

If you are looking for a way to cut assembly costs, maybe Fafnir can help you through better, more economical use of bearings. The Fafnir Bearing Company, New Britain, Conn.

MOST COMPLETE LINE IN AMERICA

FAFNIR BALL BEARINGS

WHAT A YEAR WE'VE HAD AT HOLO-KROME!

Seems like every time we turned around someone came up with a new idea on service, packaging or products to help our distributors and their customers

BUT '55 WAS NOTHING—WATCH '56! GREAT THINGS ARE HAPPENING AT— HOLO-KROME

THE HOLO-KROME SCREW CORP., 25 BROOK ST. •• HARTFORD 10, CONN.

SAME-DAY SERVICE purred along smoothly in high gear all year long. Each inquiry was quoted on or acknowledged by telegram the same day it came in.

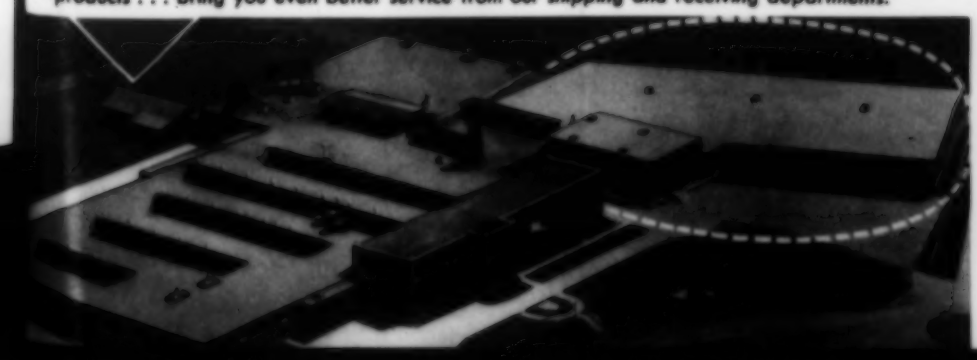
ONE and TEN-PAKS to slash distributor's Broken-Package problem, manufacturer's handling costs.

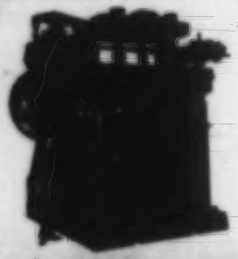
THE PRE-PAK PLAN for a new and revolutionary approach to cutting handling costs.

NEW BOXES, sturdier cases, improved labels to assist everyone who handles Holo-Krome products.

SLIDING SHELVES to speed orders through our own plant and give you better service.

NEW PLANT WING and new equipment to meet the increasing demand for H-K products . . . bring you even better service from our shipping and receiving departments.





"NO SHUT-DOWNS WITH LUBRIPLATE"

—say HENRY & WRIGHT of Hartford, Conn.

"While waiting for delivery of one of our 25-ton Dieing Machines to do a particularly heavy job, a customer was trying to start production of a 10-ton machine. Even though it was lubricated with a conventional grease every eight minutes, the machine had to be shut down for bearings to cool during each coil run. Then, on our recommendation, he changed to a LUBRIPLATE Lubricant. With but two applications of LUBRIPLATE a day, the machine operated continuously except during change of coils."

REGARDLESS OF THE SIZE AND TYPE OF YOUR MACHINERY, LUBRIPLATE GREASE AND FLUID TYPE LUBRICANTS WILL IMPROVE ITS OPERATION AND REDUCE MAINTENANCE COSTS.

LUBRIPLATE is available in grease and fluid densities for every purpose... LUBRIPLATE H. D. S. MOTOR OIL meets today's exacting requirements for gasoline and diesel engines.

For nearest LUBRIPLATE distributor see Classified Telephone Directory. Send for free "LUBRIPLATE DATA BOOK"... a valuable treatise on lubrication. Write LUBRIPLATE DIVISION, Fiske Brothers Refining Co., Newark 5, N. J. or Toledo 5, Ohio.

News Roundup

(*Continued from Page* 31)

through flexible tubing.

Accuracy of the hydraulic load measuring system is within ½ per cent of dial reading. Six load measuring scales are provided, the lowest of which has a capacity of 20,000 lb on which load variations as small as 20 lb can be indicated.

Amsler repeated load equipment is included in the big machine's accessories. It consists of a completely integrated set of jacks, pumps and load measuring devices especially designed to apply and measure repeated loads on structures, structural members or machine parts. Loads up to 100 tons can be applied at a rate of 250 to 500 cycles per minute. For designers, these capabilities simulate the experience on a structure over a lifetime of service.

Annual A. F. Davis Welding Award for 1955 was presented to Monroe Edwards of Georgia Institute of Technology for his paper entitled "Welding Faces Automation." A second prize was awarded William J. Gress of the University of Florida for an article entitled "Welding, A Way of Thinking."

This annual award, directed by the American Welding Society, is sponsored by A. F. Davis, vice president and secretary, Lincoln Electric Co. Details on competition for next year's award may be obtained from the American Welding Society, 33 West 39th Street, New York 18, N. Y.

Air and gas lubrication is being studied by the newly formed Air Glide Laboratories, Vermilion, Ohio. All phases of air and gas-film lubrication research are under the direction of Fred Macks, consulting engineer. Facilities are available for research, development and manufacture of air and gas bearings, gas bearing systems and seals.

Clevite Corp. has acquired **Intermetal G.m.b.H.** of Dusseldorf, Germany, the second largest company in Europe engaged in the development and manufacture of

There are BIG advantages of shifting over to the ELECTRONICS INDUSTRY!

1. It is the leading growth industry.
2. It is turning more and more to automatic production.
3. Increasing mechanical problems have to be met in the development of advanced electronic equipment.

There are BIG advantages of going with BENDIX RADIO!

1. Bendix Radio is a leader and pioneer in its field, with many challenging openings for designers and draftsmen.
2. Bendix Radio is growing FAST. Therefore, it offers outstanding advancement possibilities in the electro-mechanical field.
3. At Bendix Radio, you will benefit from top pay, ideal working conditions, all employee benefits and pleasant living in beautiful residential area. RELOCATION EXPENSES PAID!

All you need to do is drop us a postal card! Briefly state your education and experience. We promise immediate response.

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DIVISION OF BENDIX AVIATION CORP.
TOWSON 4, MARYLAND

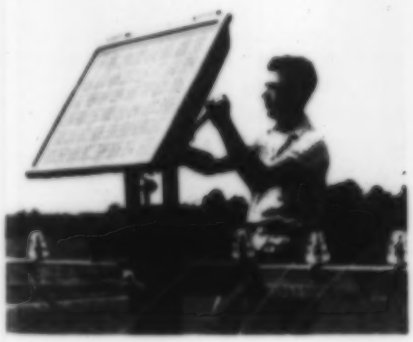
transistors and diodes, president William G. Laffer announced. Intermetal will be operated in conjunction with Transistor Products Inc., a Clevite operating unit in Waltham, Mass. Transistor Products is in the field of high-power transistors, and supplies germanium diodes to the television industry in this country.

Sun Power Runs Phone Line

Experimental Project Uses New Solar Battery

NEW YORK, N. Y.—Power from the sun is being directly converted into electrical power using a newly developed silicon cell. Bell Telephone Laboratories recently began operation of a rural telephone installation powered entirely by a bank of the newly developed cells.

Because power output of the solar battery is low, vacuum tubes were replaced by transistors in the amplifier and other electronic circuits of the sytem. Transistors require merely a fraction of the power necessary to operate conventional vacuum tubes.



Pole-top installation of Bell Laboratory's solar battery. The bank consists of 432 silicon cells producing about 100 watts per square yard of effective surface

Direct sunlight is not essential to the generation of power by the unit. Lower light levels still produce power, but in reduced amounts. A storage-battery unit is charged by the bank of cells and acts to keep the telephone system in operation at night and during

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TAKE ADVANTAGE of Yale & Towne's skilled engineering assistance on your powdered metal problems.

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Brute Strength or Delicate Handling of Rotary Power Functions . . .

TWO VANES ARE BETTER THAN ONE

The hydraulically balanced DUAL-VANES in DUDCO Fluid Motors, as contrasted with conventional designs, maintain MULTIPLE AREAS OF CONTACT ON THE CAM RING . . . doubling the number of effective barriers to slippage and power loss. This patented principle is an exclusive DUDCO feature!

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FLUID MOTORS

Compact and sturdy, DUDCO DUAL-VANE Fluid Motors operate quietly and smoothly under the most strenuous conditions. They're built to "take it" . . . frequent reversals, rapid accelerations or stalling under load. With DUDCO you get the big advantage of 2000 psi operation at a cost comparable with that of lower pressure equipment.

DUDCO is a big, exciting story for every hydraulics engineer because . . . power losses are minimized and operating efficiency is higher . . . starting torques are high . . . operation is smooth, quiet and exceptionally free from wear or maintenance problems.

On Conveyor systems for agricultural, food processing, mining and other industries, DUDCO DUAL-VANE Fluid Motors provide the extras in performance that save time, money and labor. Operating

the winches on a giant tank retriever and other large mobile equipment calls for high starting torque and the dependable power of DUDCO DUAL-VANE MOTORS.

Write for Bulletin DM-301 fully describing DUDCO DUAL-VANE Fluid Motors today!

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THE NEW YORK AIR BRAKE COMPANY
1706 EAST NINE MILE ROAD • HAZEL PARK • MICH.
INTERNATIONAL SALES OFFICE, 90 WEST ST., NEW YORK 6, N. Y.

periods of extremely dark weather.

Each cell is about the size of a quarter. The entire bank consists of 432 of these cells, cushioned in oil and covered by glass. Power output is 100 watts per square yard

Storage battery is charged by the sun-operated battery to carry the electrical load of the telephone system at night and during periods of extremely cloudy, dark weather

of effective surface. Efficiency is 11 per cent.

Solar batteries are not scheduled for wholesale installation in the near future, according to Bell Labs. This telephone-line installation is merely experimental. However, results indicate that low amounts of power may be provided economically where commercial power is not available.

Society of Industrial Designers has voted to change its name to American Society of Industrial Designers, Peter Muller-Munk, president, announced. New president installed at the recent ASID meeting in Washington, D. C. is Arthur N. Becvar, manager, industrial design, Major Appliance Div., General Electric Co.

Electric Service Engineering Co., Joliet, Ill., has been purchased by H. K. Porter Co. Inc., it was announced by T. M. Evans, Porter's president. Electric Service specializes in the design and manufacture of electrical and electronic devices used in heavy industry and in cer-

tain government departments, including the armed forces. It will be known as the Eseco Div., H. K. Porter Co. Inc.

Chrome Coat Hardens Steel

High-Temperature Diffusion Forms Alloy Surface Layer

NEW YORK, N. Y.—Heat, wear and corrosion resistance of ferrous metals is increased by high-temperature diffusion of chromium into the surface. Called "Chromallizing," the process is reported to be well known in Europe and is now coming into use in this country.

According to Chromalloy Corp., the process results in chromium being diffused into the base metal to form an alloy layer. The layer thus formed is said not to spall, peel or flake.

The process can develop a ductile case (0.001 to 0.003-in.) of chromium on low-carbon steel. On steels of medium to high carbon content, a thin (0.0002 to 0.0010-in.), extremely hard (Vickers 1800) chromium carbide case is formed.

While ductile cases are found to run as high as 50 per cent chromium at the surface, the alloying material is not used in great quantity because of the limited depth of the case. Treated in this manner, low-carbon steels may be used in applications requiring a Type 400 series stainless steel.

Reported successful uses of the process include electric strip heaters, turbine liners and various aircraft units.

Hi-Fi Collection Is All Noise

FT. WAYNE, IND.—A recording library consisting of a collection of noise records is being compiled at the General Electric sound analysis laboratory.

Recordings of electrical motor and transformer noise are being made to aid in study of noise sources. Various noises will be compared by means of the recordings.

(*Continued on Page 42*)

Arm-weary tractor operators are grateful for TD-14A and TD-18A International Harvester crawlers. They steer with the ease of a late model car for each track is controlled by its own hydraulic circuit...a booster system with velvet smooth, positive action that stems from

HYDRECO
Oil Power

Here is a HYDRECO dual pump that delivers 5 gpm to each circuit at 1200 rpm against a system pressure of 700 psi. The dual pump provides a circuit for each track and the result . . . no arm-weary operators . . . more accomplished with less effort, in less time . . . smoother, higher performance . . . lower maintenance.

For engineers seeking practical answers to problems of trouble-free hydraulic controls, better performance, added functions and greater sales appeal for mobile equipment, the experience of HYDRECO engineers offers a definite answer!

WRITE— *for latest literature and full information on new developments in HYDRECO Pumps, Motors, Valves, and Cylinders.*

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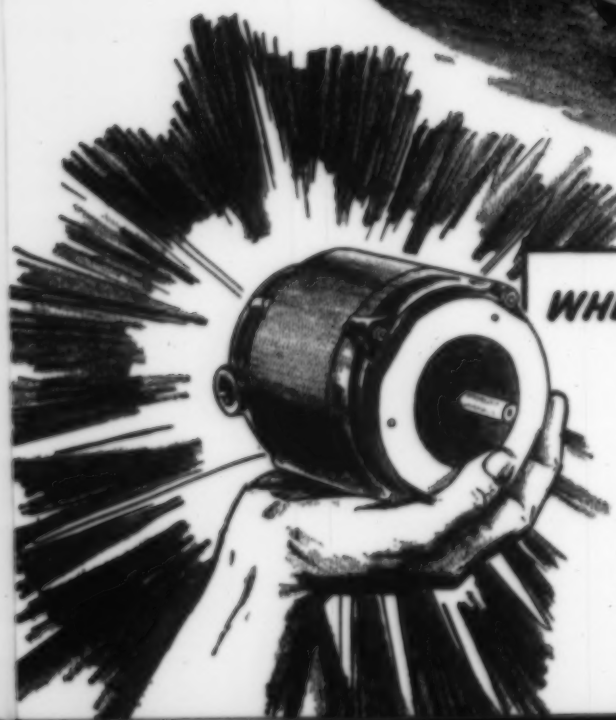
G.E. OFFERS SPECIAL SOLUTIONS FOR YOUR SPECIAL ELECTRIC-DRIVE PROBLEMS

DID YOU KNOW GENERAL ELECTRIC'S SPECIALTY COMPONENT MOTOR DEPARTMENT DESIGNS AND BUILDS THOUSANDS OF SPECIAL MOTORS AND GENERATORS TO SOLVE SPECIAL ELECTRIC-DRIVE PROBLEMS ON YOUR PRODUCTS? THIS DEPARTMENT'S COMPLETE SPECIALTY-MOTOR LINE INCLUDES A WIDE VARIETY OF SMALL AC AND DC MOTORS AND GENERATORS, ALTERNATORS, AMPLIDYNES, TACH GENERATORS, DYNAMOTORS, AND UNIVERSAL MOTORS. AND THE G-E MOTOR ENGINEERS READY TO WORK WITH YOU WILL EXPERTLY MODIFY BASIC DESIGNS TO PROVIDE THE CHARACTERISTICS, ENCLOSURE, SIZE AND SHAPE, AND SPECIAL ACCESSORIES **YOU** REQUIRE FOR **YOUR PRODUCTS.**



WHERE CAN YOU USE THIS NEW, GEARLESS LOW-SPEED AC MOTOR?

ONLY G.E. OFFERS THIS SYNCHRONOUS INDUCTOR MOTOR—OPERATING AT LOW SPEED ON 115 OR 230-VOLT AC POWER. LIMITLESS USES INCLUDE MOTOR-OPERATED VALVES, MACHINE TOOLS, REMOTE-CONTROL SYSTEMS. RAPID ACCELERATION, DECELERATION, REVERSING. SEALED-IN LUBRICATION FOR LONG LIFE.

TWO MODELS: 75 RPM, 75 OZ-IN.; 100 RPM, 2 OZ-IN.

specialty motors

SPECIAL G-E ALTERNATOR PUTS PINEAPPLE HARVESTING ON A 24-HOUR BASIS

... SPECIALLY DESIGNED G-E ALTERNATORS—RATED FOR CONTINUOUS DUTY IN AMBIENT TEMPERATURES UP TO 120°F—NOW PROVIDE POWER FOR FLOODLIGHTS AND SMALL HAND TOOLS ON HUGE PINEAPPLE HARVESTING MACHINES. THIS PERMITS HAWAII'S PINEAPPLE GROWERS TO OPERATE ROUND-THE-CLOCK TO GATHER THE FRUIT AT THE PEAK OF PERFECTION. **G-E APPLICATION "KNOW-HOW" PLUS QUALITY DESIGN AND MANUFACTURE** ASSURE LOW MAINTENANCE, MINIMIZE DOWNTIME.

AVAILABLE: COMPLETE ENGINEERING ASSISTANCE FOR YOU!

HERE'S THE SPECIAL ATTENTION YOUR PROBLEMS GET AT G.E.: **1.** YOUR LOCAL G-E APPARATUS SALES ENGINEER LEARNS ALL ABOUT YOUR NEEDS FROM YOUR DESIGN PEOPLE. **2.** HE CALLS IN A TEAM OF FACTORY ENGINEERS WITH YEARS OF MOTOR APPLICATION EXPERIENCE. **3.** AT THEIR DISPOSAL ARE G.E.'S COMPLETE DEVELOPMENT AND TESTING FACILITIES. **4.** IN SHORT ORDER, A SAMPLE G-E MOTOR IS READY FOR TESTING ON YOUR PRODUCT.

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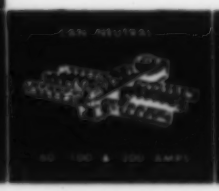

The Answer to Your *SEALING PROBLEMS* in the Palm of Your Hand

DURA SEAL

. . . an engineered rotary mechanical seal that is made to meet YOUR SPECIFIC SEALING NEED using selected alloys, carbons and ceramics.

In general, Dura Seals can be installed on new or existing equipment—no sleeves or special machining necessary.

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Send your sealing problems to us for free counsel

The PERFECT SEAL

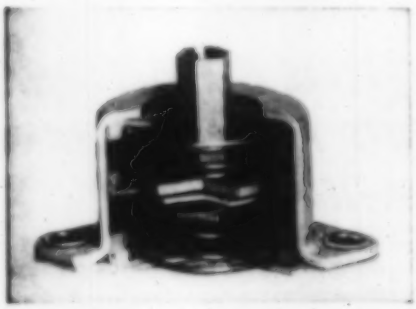
DURAMETALLIC CORPORATION
KALAMAZOO MICHIGAN

News Roundup

(*Continued from Page* 39)

In this way noise sources can be identified and corrected.

Microphones are suspended from the ceiling and connected to recording equipment outside the room. No one is permitted in the room during tests because the human body reflects sound and is not capable of remaining motionless.



VIOLENT MANEUVERS by jet airplanes are said to be easily absorbed by this vibration isolator, according to Barry Controls Inc. Made to absorb vibrations at any angle of mounting, the device rests at its midpoint at no load. Damping is equal in all directions

Power Lines Carry Automatic Control Signals

Remote control System May Time All Plant Operations

NEW YORK, N. Y.—Remote control of motors, valves and lights without special wiring is among the possible uses of a recently announced "electronic supervisor." Designed by International Business Machine Corp., the system sends carrier-current signals over existing electric supply lines to control up to 40 groups of remote operations. Each of the controlled functions may be on its own time schedule.

A single building or several buildings scattered over several acres may be covered by the IBM system. Components and operation are relatively simple.

Electronic pulses of from 2106

to 19,000 cps are superposed on the plant's electrical distribution system. These pulses or "commands" originate in a central operations unit. Automatic programming on a predetermined schedule may be set up.

One feature of the system is that time recording and time indicating equipment, including secondary wall clocks, may be automatically synchronized with a radio-controlled master clock supervised by the National Bureau of Standards radio time signals. In addition, audible signals such as the plant whistle may be sounded electronically to indicate starting and stopping times in the morning and evening and at lunch and rest periods during the day as well—all without special wiring.

In the IBM carrier system, an electronic or rotary transmitter is coupled to the 60-cps ac lines at the distribution voltage to assure complete power system coverage. Typical IBM installations include signal injection into alternating-current electrical distribution systems of from 110 volts to 13,800 volts. In the majority of electrical systems, satisfactory coverage is obtained by coupling directly to the 115 volt lighting distribution system. In some instances, however, plant-wide coverage requires coupling to high-voltage distribution systems of up to 13,800 volts and frequently may involve areas of many square miles. In either case, the IBM system is said to completely cover the area for electronic remote control.

The IBM system is capable of transmitting and executing 40 "on" and 40 "off" commands by use of only four carrier frequencies. An encoding device is employed at the central control. An electromechanical decoding device at remote locations responds to coded pulses of the proper frequency.

Source of the system's directions or commands is the central operations panel. Program machines are provided for automatic scheduling of operations on a weekly basis. The schedule may be varied automatically for any day of the week. Saturday and Sunday operations, for example, may be on an entirely different schedule than those of

Now—all from one source

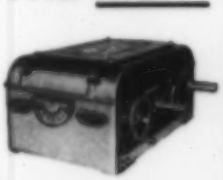
- VARI-SPEED MOTOR PULLEY
- ADJUSTABLE MOTOR BASE
- VARI-SPEED BELT
- RELIANCE Ac MOTOR
- DRIVEN PULLEY

REEVES

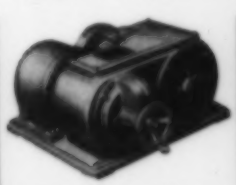
Vari-Speed Motor Pulley

This simple, compact REEVES unit provides an economical way to widen machine range, and an efficient method of adjusting work flow to changing conditions. Speed variations are effected smoothly and instantly—without stopping the machine! Unit also available without motor. For bulletin complete with rating charts and dimensions, write Department H18b-V545.

THE RIGHT SPEED FOR EVERY NEED!



Transmission
Heavy duty—2:1 to 16:1 range—fractional hp. to 87 hp.



Vari-Speed Motodrive
Compact—2:1 to 6:1 range—sizes to 40 hp.—fractional with 10:1.

Flexi-Speed
Versatile, economical—8:1 range—½, ¾ and 1 hp.

The wide range of REEVES variable speed equipment is now supplemented by the line of Reliance drives. Now—more than ever—you can rely on your REEVES representative for the answer to any speed control problem.

REEVES PULLEY COMPANY, COLUMBUS, INDIANA
Division of RELIANCE Electric and Engineering Co.

week days.

Inactivating switches are associated with each on-off circuit to provide a means for making any programmed circuit inoperative to prevent transmission of command pulses normally scheduled for a circuit. Pilot lamps indicate which commands were last transmitted on each circuit. In addition, a manual control section is provided for initiating commands manually on a nonscheduled basis and also to change the status of circuits normally operating on a prescheduled basis. Interlocks preclude possibility of a manually initiated signal interfering with one that may be automatically scheduled at the same instant, and vice versa.

A sensing unit in the central operations panel automatically detects and decodes the carrier signal. In the event the transmitter fails to key, or if it fails to transmit a signal of sufficient voltage level to reach all remote units connected to the system, the sensing unit will prevent changes in the indicating lights associated with each circuit.

Extra or repetitive commands may be scheduled throughout the day to restore to an "on" or "off" status, as required, any remote unit that may have been operated manually for periods not included in the prescheduled program. Coded relays also provide key lockout to prevent unauthorized switching at the remote point.

An important feature of the central operations panel is its "building block" design. Program machines are pluggable, as are the circuit relays. In addition, a plugboard is provided to facilitate future changes in circuit arrangement or capacity.

Besides operating by carrier current, IBM central control systems also may operate via control circuits directly wired from the operations panel to the terminal unit. A single pair of control wires will provide control of ten on-off circuits. Each additional wire available will increase the number of control circuits by ten.

Receivers connected to 60-cps electrical outlets in the system reject all frequencies except those to which they are tuned. When a

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VARIABLE SPEED
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ROTO-DRIVE
Speed variation up to 8 to 1.
Mounts in any position.
No adjustable motor base.
Operates on fixed centers.
LOW COST—Saves 40% compared with conventional motordrives.

ROTO-CONE

Offers up to 4 to 1 speed variation.
V to V drive.
Exclusive design permits V-belt to travel on fixed center line.
Easily installed. HP ranges fractional through 20.

VAR'A'CONE

For fractional HP requirements. Uses "A" section V-belt.

Up to 2¾ to 1 speed ratios.
List price low as $5.40. 3 sizes.
An efficient and low cost method of adding variable speed.

Complete selection standard variable speed belts, standard and countershaft adjustable motor bases, companion sheaves, and flexible couplings.

Write for 30-page Catalog

Gerbing MFG. CORP.
Dept. MD-11
Northbrook, Ill.
(A Suburb of Chicago)

signal of correct frequency is detected, the receiver actuates the decoding unit. If electronic pulses of the correct frequency appear at properly spaced time intervals, a dual-coded relay will cause an "on" or "off" function to be performed as directed by the central operations panel.

"It's driving me crazy! I simply can't stop thinking."

Air Force to Install Largest Computer Center

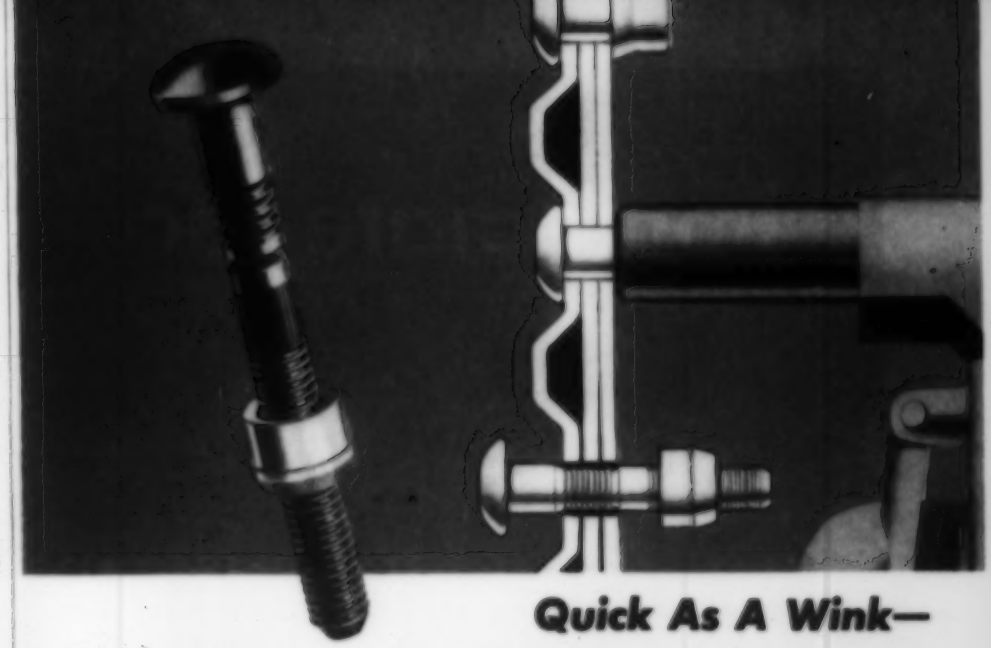
New Electronic Lab To Tackle Flight Problems

NEW YORK, N. Y.—Air Research Development Command officials announced plans for a new computer center for the Air Force. To be constructed in Dayton, the facility is expected to be the largest computer center in the U. S. Research on problems in aircraft design and guided missiles will be handled on the latest computer equipment.

To be built by Reeves Instrument Corp., the computer will be designed specifically for handling special problems involved in the development of weapons systems. Over 500 operational amplifiers and allied equipment are expected to make the capacity of the device larger, and the machine faster and more versatile than any other large-scale differential analyzers in the country.

Although similar in its basic op-

(*Continued on Page* 48)



Quick As A Wink—

You Get Secure, Permanent Fastening With Townsend Lockbolts

In less than a second, with one squeeze of the trigger, a Townsend lockbolt pulls the work together with a high clinching action, is locked in place with uniform pressure. It is a quick method of producing tight, rigid, permanent fastenings that cannot loosen even under extreme vibration or shock conditions.

Townsend lockbolts combine the advantages of riveting and bolting—eliminate the disadvantages. Installation is fast—under certain conditions, one man will install 30 in only 60 seconds. Fewer workers will complete an assembly in less time than when riveting or bolting.

The clamping action, or clinch, of Townsend lockbolts is higher than rivets—is more uniform than bolts and nuts. The lockbolt fills the hole better than other fasteners, thus making possible a more rigid joint and also providing an effective liquid seal.

The Townsend lockbolt consists of two precision-made parts—a pin and a collar. Locking grooves are provided on the pin into which the collar is swaged by the pneumatic gun. The pulling section of the pin breaks in tension at a predetermined point when the setting action is completed.

Townsend lockbolts are available in steel and aluminum alloy, in 3/16", 1/4", 5/16" and 3/8" diameters, in grip lengths ranging up to 2", in various head styles. For information on how to speed production, get tight, secure, permanent fastening with Townsend lockbolts, use the coupon below.

Licensed under Huck patent nos. RE 22,792; 2,114,493; 2,527,307; 2,531,048; 2,531,049.

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*Life-Line*starters*

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265 warehouses in over 175 cities across the nation are stocked with Westinghouse Life-Linestarters—sizes 0 through 4.

. . . and that fact means immediate delivery to you of the most modern starter in its field with exclusive features like (1) inverted clapper-type armature that eliminates sticking and jamming (2) bimetallic overload relay that retains its calibration indefinitely. And common modifications can be shipped within 2 weeks.

Call your Westinghouse sales engineer today for more such practical solutions to your everyday problems on motor control. He's backed by the most complete line in the industry—and the most extensive network of service. J-21919

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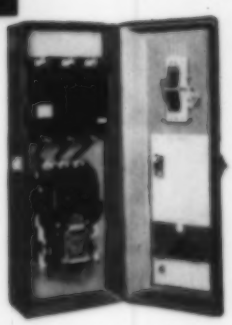
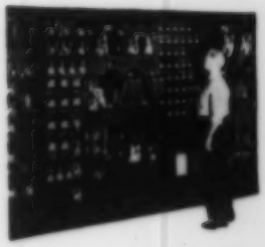
YOU CAN BE SURE... IF IT'S
Westinghouse

CONTROL COMPONENTS



INDIVIDUAL MOTOR CONTROL

ELECTRONIC CONTROL



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MARK-TIME
TIMING DEVICES

better

your product . . .
better your company's

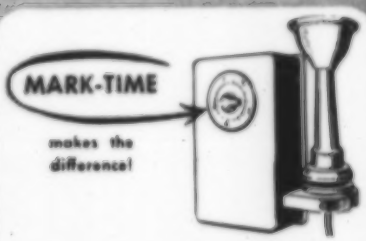
profits

Mark-Time adds value to any product because it provides extra convenience and utility — with more profit to you!

PROFIT FROM MARK-TIME'S 25 YEARS OF EXPERIENCE as the world's largest exclusive designers and manufacturers of mechanical timing devices.

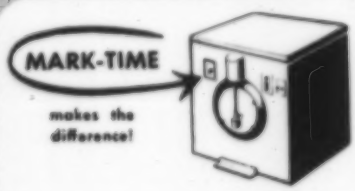
A SPECIALIZED ENGINEERING STAFF is ready at any time to work with you to design or adapt a timer or time control unit for your specific product.

MARK-TIME
has a TIMER
for every purpose!



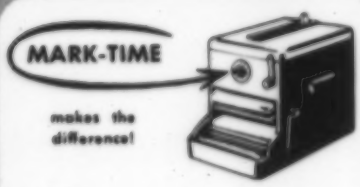
A built-in Mark-Time automatic time switch controls this versatile cold Ultra Violet Lamp used in medical diagnosis. Only one example of how dependable Mark-Time units perform important functions on many leading brands of medical equipment.

MARK-TIME TIMERS



The fast-growing popularity of soft served frozen milk products has widened a profitable market for the manufacturers of freezer-dispensers. Mark-Time automatic time switches are widely used in these units to provide dependable accurate timing of the freezing cycle.

MARK-TIME TIMERS



Built-in Mark-Time automatic time switch controls the exposure interval for a portable office copying unit which is finding wide acceptance in offices making multiple copies in less than a minute. One more example of how Mark-Time adds "sales appeal" to products for business.

MARK-TIME TIMERS

MARK-TIME 25th YEAR

M. H. RHODES, INC.
HARTFORD 6, CONN

Manufactured and Sold in Canada by:
SPERRY GYROSCOPE OTTAWA Ltd., Ottawa, Ontario, Canada

News Roundup

(*Continued from Page 45*)

eration to other large-scale electronic computers, this model will introduce new features and refinements perfected to keep pace with recent technological advances in the whole field of aviation. Mainly, these developments concern greater reliance on automatic controls and other techniques to minimize human operator errors, permit validation of solutions, and provide new operational convenience.

Among these innovations is a "problem check" to check the programming of the problem and subsequent phases of computer performance. Among the other refinements are multiple computer time scales available at the flick of a switch, indications that computing components have been used in their optimum range during the course of the problem, and typewriter keyboard input devices for setting scale factors and arbitrary functions of several variables into the machine.

Also included will be an automatic machine programmer, which permits the operators to perform large numbers of runs automatically without manually resetting computer controls or problem parameters. Another special feature will provide automatic digital verification of computer "patching" for the particular problem being solved, as well as a printed record of the machine setup.

Visual indicators consisting of alarms or signals are provided at certain critical test points. Thus, the machine will be able to detect its own malfunctioning components and pinpoint their location, enabling the operator to make the necessary corrections.

Rototest Laboratories, Lynwood, Calif., is expanding its facilities for environmental qualification and reliability testing of electrical and electromechanical components.

High purity aluminum pig—containing 99.99 per cent, or more, aluminum—is now being produced in commercial quantities by Kaiser Aluminum & Chemical Corp. The metal will be rolled into foil for

the electronics industry, and will also be made available to other commercial users in pig form.

Meetings

AND EXPOSITIONS

Nov. 16-18—

Steel Founders' Society of America. Tenth Annual Technical and Operating Conference to be held at the Carter Hotel, Cleveland, O. Additional information may be obtained from society headquarters, 920 Midland Bldg., Cleveland 15, O.

Nov. 17-18—

American Society for Quality Control. Tenth Mid-West Conference to be held at Hotel Schroeder, Milwaukee 1, Wis. Additional information may be obtained from R. H. Byrnes, 3402-A N. Humboldt Ave., Milwaukee, Wis.

Nov. 27-30—

American Institute of Chemical Engineers. Annual Meeting to be held at the Statler Hotel, Detroit, Mich. Additional information may be obtained from society headquarters, 25 West 45th St., New York 36, N. Y.

Nov. 28-Dec. 1—

Air Conditioning & Refrigeration Exposition to be held in Atlantic City Auditorium, Atlantic City, N. J. Sponsored by the Air Conditioning & Refrigeration Institute. Additional information may be obtained from F. G. Coggin, Chairman, Detroit Controls Co., Detroit, Mich.

Dec. 1-3—

American Society of Refrigerating Engineers. Annual Meeting to be held at the Traymore Hotel, Atlantic City, N. J. Additional information may be obtained from society headquarters, 234 Fifth Ave., New York 1, N. Y.

Dec. 5-9—

25th Exposition of Chemical Industries to be held at Commercial

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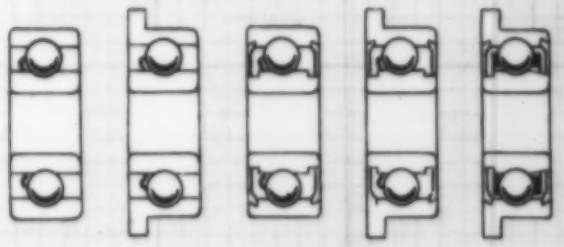

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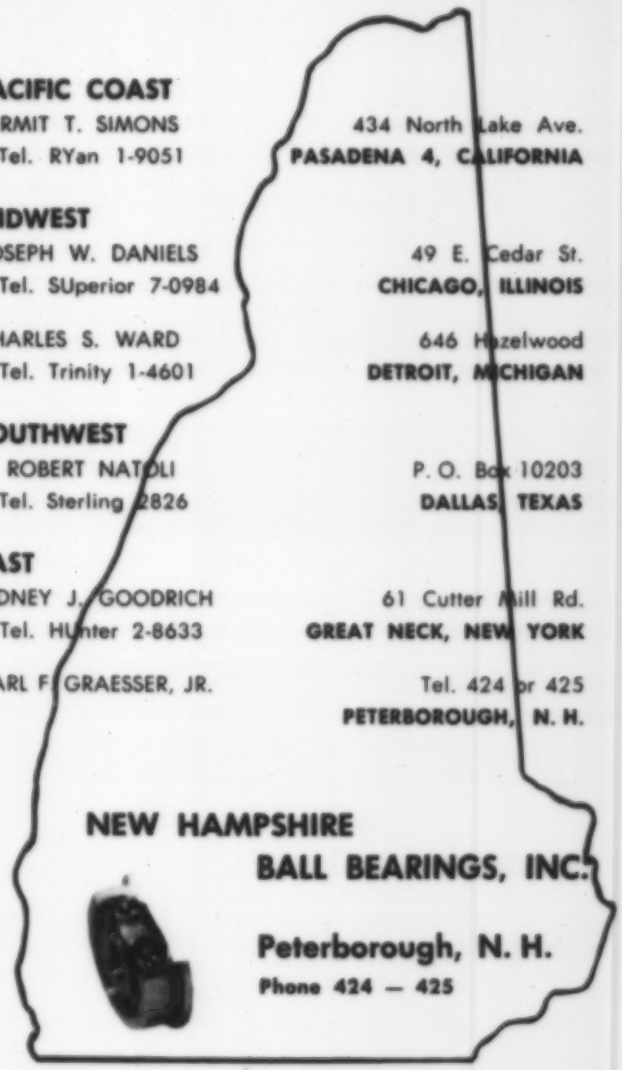

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Museum & Convention Hall, Philadelphia, Pa. Additional information may be obtained from E. K. Stevens, Manager, 480 Lexington Ave., New York 17, N. Y.

Dec. 11-14—

American Society of Agricultural Engineers. Winter Meeting to be held at the Edgewater Beach Hotel, Chicago, Ill. Additional information may be obtained from Frank B. Lanham, Secretary, St. Joseph, Mich.

Dec. 10-16—

International Atomic Exposition to be held at the Public Auditorium, Cleveland, O. Sponsored by the American Institute of Chemical Engineers. Additional information may be obtained from Athel F. Denham, Director, 931 Book Bldg., Detroit 26, Mich.

Dec. 12-16—

Nuclear Engineering & Science Congress to be held at the Public Auditorium, Cleveland, O. Additional information may be obtained from the Engineers Joint Council, 29 West 39th St., New York 18, N. Y.

Jan. 9-13—

Society of Automotive Engineers. Annual Meeting to be held at the Sheraton-Cadillac Hotel and Hotel Statler, Detroit, Mich. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Jan. 23-26—

Plant Maintenance & Engineering Show to be held at Convention Hall, Philadelphia, Pa. Additional information may be obtained from Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

Jan. 23-27—

Institute of the Aeronautical Sciences. Twenty - fourth Annual Meeting to be held at Hotel Sheraton-Astor, New York, N. Y. Additional information may be obtained from society headquarters, 2 East 64th St., New York 21, N. Y.

Jan. 24-27—

American Management Association. General Management Conference to be held at Hotel Fairmont, San Francisco, Calif. Additional information may be obtained from society headquarters, 330 West 42nd St., New York 36, N. Y.

Jan. 30-Feb. 3—

American Institute of Electrical Engineers. Winter General Meeting to be held at Hotel Statler, New York, N. Y. Additional information may be obtained from society headquarters, 33 West 39th St., New York, N. Y.

Feb. 1-2—

Midwest Welding Conference to be held at Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill. Sponsored jointly by the Foundation and the Chicago section of the American Welding Society. Additional information may be obtained from Harry Schwartzbart, conference chairman, 35 West 33rd St., Chicago 16, Ill.

Feb. 7-9—

The Society of the Plastics Industry, Inc. Eleventh Annual SPI Reinforced Plastics Division Conference to be held at Hotel Chalfonte-Haddon Hall, Atlantic City, N. J. Additional information may be obtained from society headquarters, 67 West 44th St., New York 36, N. Y.

Feb. 27-Mar. 2—

American Society for Testing Materials. National Meeting to be held at Hotel Statler, Buffalo, N. Y. Additional information may be obtained from society headquarters, 1916 Race St., Philadelphia 3, Pa.

May 24-25, 1956—

Third Conference on Mechanisms to be held at Purdue University, West Lafayette, Ind., sponsored by the Purdue School of Mechanical Engineering and MACHINE DESIGN. Additional information may be obtained from the Editor, MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

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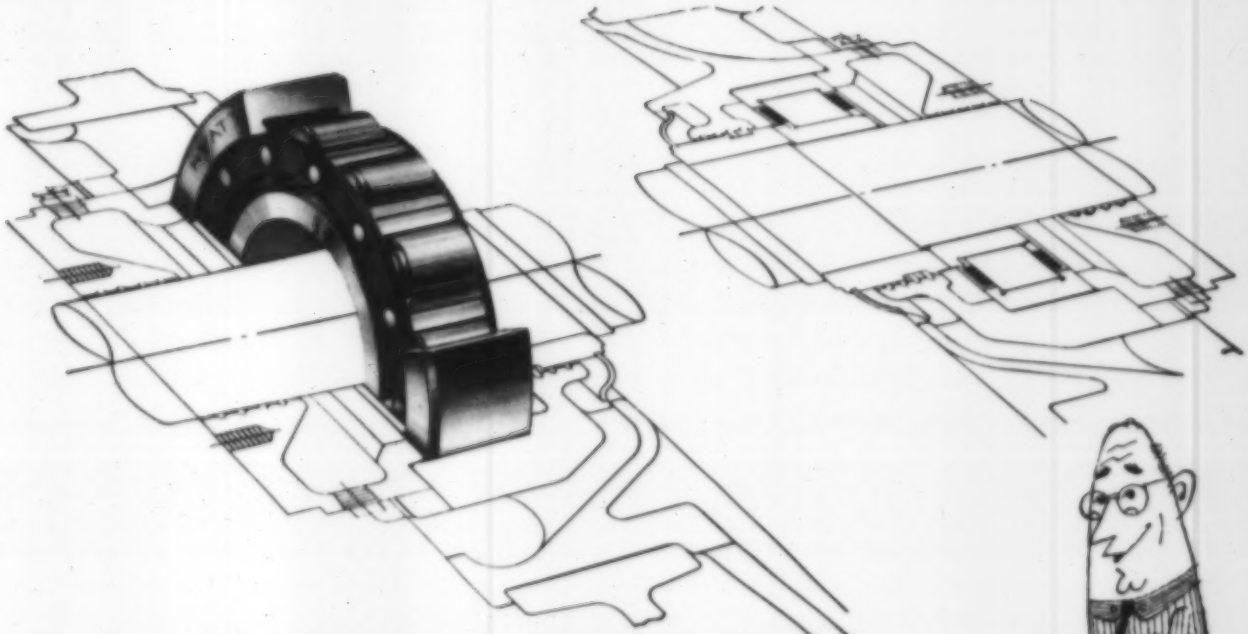
OVERCOME OVERLOADING



HY POTENUSE, the sage of the slide rule, says:

This HYATT Hy-Load is heading for a long hard life. It's been designed into as tough a job as you can hand any bearing—the armature shaft of a steel mill motor.

These HYATT Bearings must maintain the armature on centers with very close running clearance despite the fact that *steel mill motors are frequently overloaded and are regularly reversed under full load!*

But ability to "take it" isn't the only reason leading motor builders mount HYATTS on both ends of armature shafts: the offset of the flanged inner race provides vital *inbuilt, non-adjustable free end float*, permitting the armature to center itself electrically. What's more, HYATT'S *separable and interchangeable* races facilitate quick replacement of armatures.

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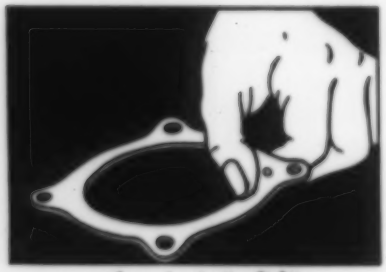

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MEN

OF MACHINES

Charles Bruning Co. Inc., Chicago, has announced the appointment of **Jack Tregay** as manager of machine development. Mr. Tregay was formerly manager of the mechanical research and engineering laboratory of A. B. Dick Co., and prior to that was chief engineer of Reynolds Electric Co.

Chief engineer of Kearney & Trecker Corp., Milwaukee, since 1952, **Orrin W. Barker** recently was elected vice president in charge of engineering. He succeeds **Joseph B. Armitage**, who will continue as vice president-consultant. Mr. Barker joined the company's engineering department in 1925 as a machine designer. In 1936 he was appointed assistant chief engineer and served in that capacity until he was named chief engineer three years ago. Previous affiliations were with the Western Cartridge Co., Ingersoll Milling Machine Co. and Nash Motor Co. Mr. Barker graduated from Milwaukee State Normal School and also attended the University of Wisconsin. He is a registered professional engineer and a member of the Society of Automotive Engineers.

Orrin W. Barker

Spencer R. Griffith

New assistant editor of MACHINE DESIGN, **Spencer R. Griffith** is introduced in "Over the Board," Page 4 of this issue.

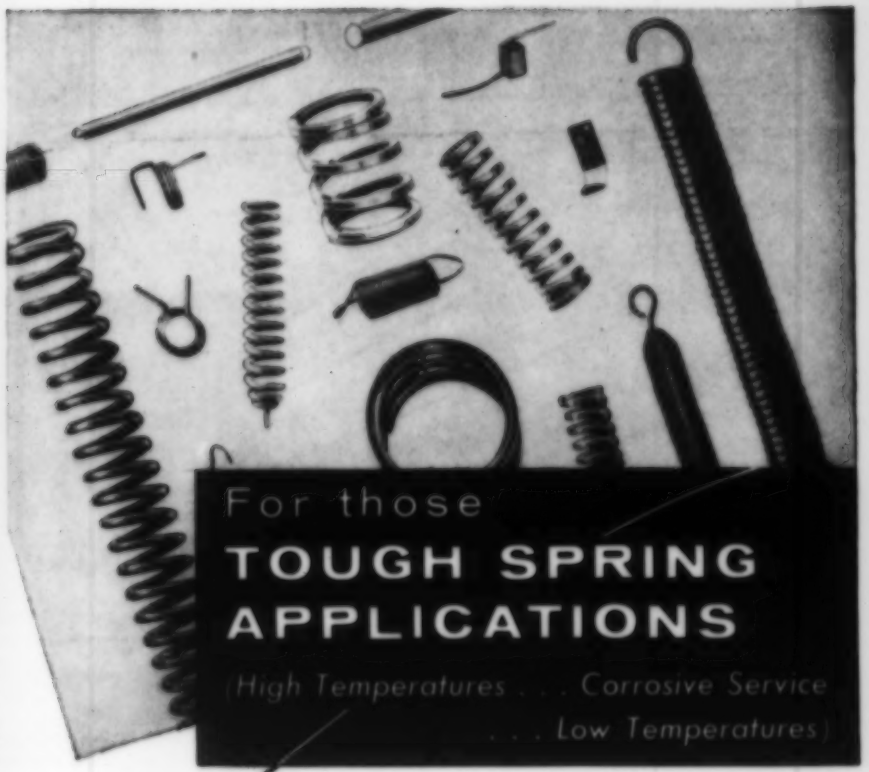
Maryland Shipbuilding & Drydock Co., Baltimore, has announced the establishment of an Industrial Products Div. and the appointment of **William F. Jameson** as engineering manager of the division.

The board of directors of the Hydraulic Press Mfg. Co., Mt. Gilead, O., recently elected **John C. Coonley** president and a member of the board.

Axelson Mfg. Co., a division of U. S. Industries Inc., Los Angeles, has appointed **Roy C. Heacock** director of engineering. He will be in charge of engineering on all of the division's machine tool, petroleum equipment and aircraft products.

Clarence E. Larson has been appointed vice president in charge of research for National Carbon Co., Cleveland, a division of Union Carbide and Carbon Corp. Dr. Larson will be in charge of all research activities.

Cook Electric Co., Chicago, has appointed **Hubert J. Thomiszer** manager of the Magnilastic Div. and **Earl Washburn** manager of the Electronic Systems Div. Both men were previously associated



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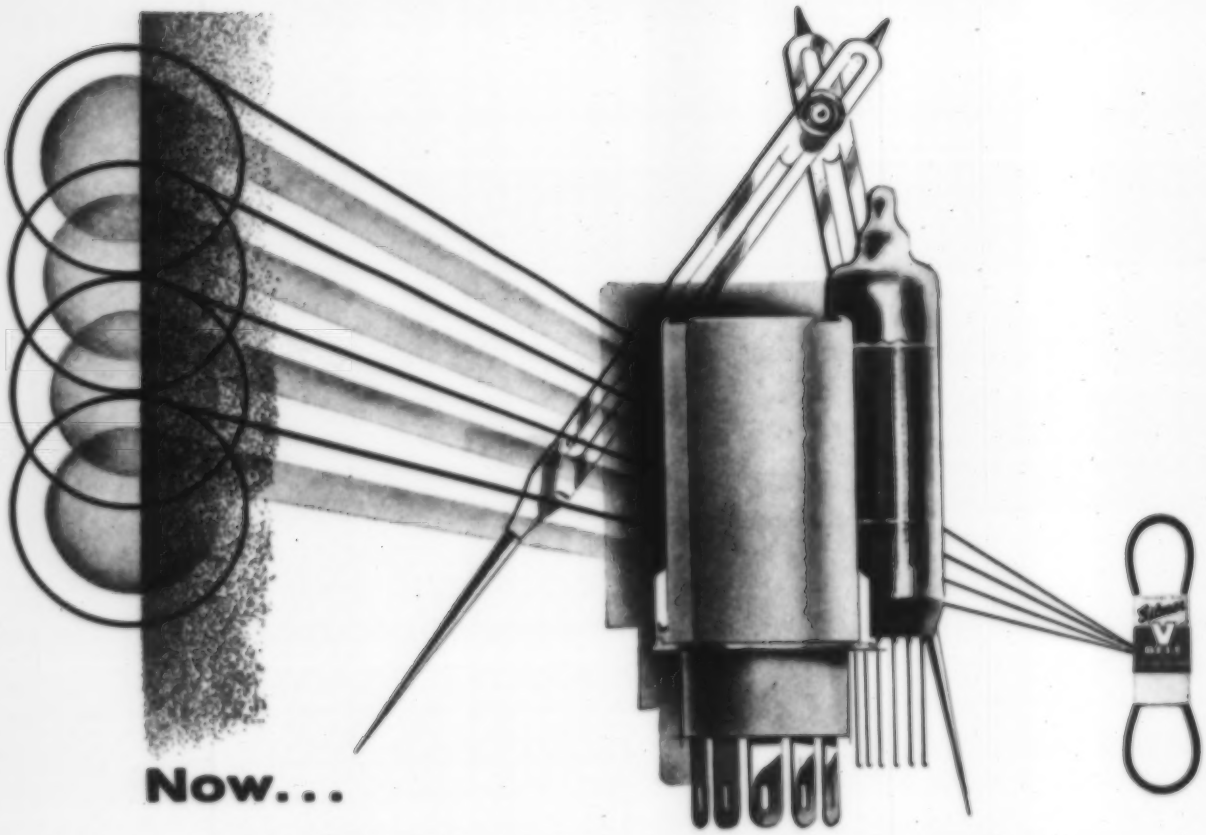

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ELECTRONIC TENSIONING—brought to you by Gilmer—is today's biggest innovation in V-belt construction...your assurance of more dependable pulling power and longer service life!

In the manufacture of most V-belts, the cord section is wound with a *mechanical* device which attempts to regulate the tension. Gilmer V-Belts used to be made this way, too...until Gilmer engineers recently perfected a new kind of tensioning device regulated by error-proof *electronics!* This assures scientifically accurate distribution of the belt's load to every strand of its cord section.

Electronic Tensioning is the latest in a series of constant improvements in the construction of Gilmer V-Belts, many of which owe their origin to Gilmer's successful development of the "Timing" Belt. That is why you can be confident that the V-belts you buy today from your NYB&P-Gilmer Distributor embody the most advanced materials and manufacturing methods to give you maximum performance and service life.

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with Cook Research Laboratories, Mr. Thomiszer as project engineer and Mr. Washburn as technical director of the systems division.

Samuel Noodleman has joined the B. A. Wesche Electric Co., Cincinnati, as vice president in charge of engineering, sales and production. Mr. Noodleman was formerly chief engineer and manager of the Standard Electric Div. of Standard Dayton Corp. A graduate of Massachusetts Institute of Technology,

Samuel Noodleman

he was engaged in research on electrical devices for radar equipment at the Radiation Laboratory of MIT during World War II. Prior to that he was with the Delco Products Div. of General Motors Corp. He is a member of the American Institute of Electrical Engineers and the Ohio Society of Professional Engineers.

The Kinney Mfg. Div. of New York Air Brake Co., Boston, recently appointed **W. H. Crowley** to the position of chief engineer. He was previously assistant chief engineer.

Virgil E. Bottom has been named director of research and development of the new transistor manufacturing plant of Motorola Inc. in Phoenix, Ariz.

Timken Roller Bearing Co., Canton, O., has appointed **John Rundt** chief engineer and **Alva Kopatz** chief draftsman of the Research and Development Div. Mr. Rundt joined the company in 1935 in the Experimental Dept.; Mr. Kopatz started in the Products Development Dept. in 1940.

Jerre Manning has been named manager of the transistor division of Minneapolis-Honeywell Regulator Co., Minneapolis.

The Gabriel Co., Needham Heights, Mass., has announced the appointment of **Steve Galagan** as director of engineering for its Laboratories and Electronics Div.

Walter G. Driscoll has been appointed assistant director of research at Baird Associates Inc., Cambridge, Mass. He will be in charge of the company's transistorized electronics department.

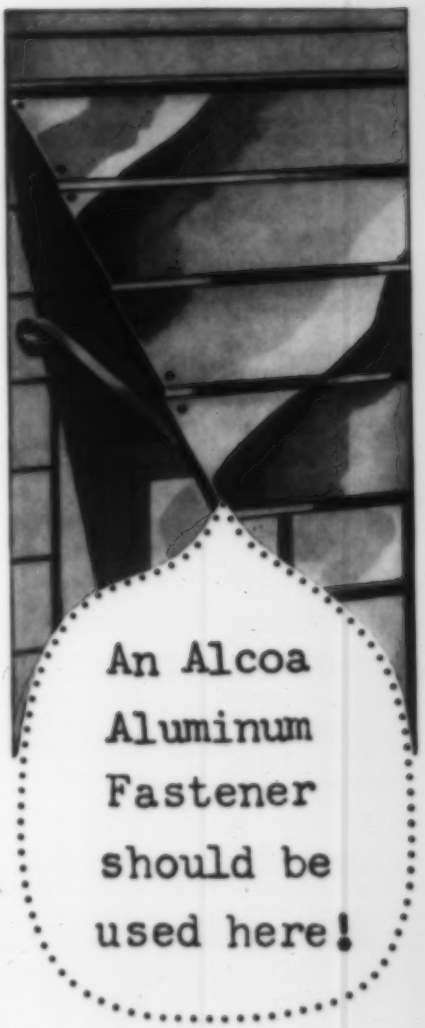
Formerly assistant chief engineer of Martin-Parry Corp., Toledo, O., **Ivor S. Campbell** has joined the Virginia Polytechnic Institute as professor of electrical engineering.

Westinghouse Electric Corp., Pittsburgh, recently announced the appointment of **Carroll V. Roseberry** as manager of the newly formed commercial atomic power activities, which will include the development, design and sale of all commercial nuclear reactors. At the same time, **William E. Shoupp** was named technical director of commercial atomic power activities.

Charles T. Oergel has been named head of the department of mechanical engineering of the Polytechnic Institute of Brooklyn. He had been associated with General Electric Co. for 26 years.

Beaver Tool and Engineering Corp., Royal Oak, Mich., has announced the appointment of **Clement Ratke** as vice president in charge of engineering.

John H. Quinn Jr. has joined the engineering department of Temco Aircraft Corp., Dallas, Tex., as chief of technical services. In this newly created position he will have a key role in preliminary work on development projects. Mr. Quinn



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*We have available a technical booklet on the Antioch Process.

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BEAN

Men of Machines

John H. Quinn Jr.

received a degree in mechanical engineering from Worcester Polytechnic Institute in 1942. During the next five years he served as an aeronautical research scientist at the Langley Field, Va., laboratory of the National Advisory Committee for Aeronautics. He then became an aerodynamics engineer at Chance Vought Aircraft Inc., where he also served in other capacities prior to joining Temco.

Theodore L. Funk has been named assistant chief engineer of McDowell Co. Inc., Cleveland. He was previously associated with Jones and Laughlin Steel Corp., where he served in various capacities including that of resident engineer of the Cleveland works.

Melpar Inc., Falls Church, Va., has promoted **Robert S. Butts** to the position of assistant chief engineer. The company also recently promoted **Robert E. Miller** to project manager of a group of sections dealing with electronic research and development.

Election of **Homer C. Gray Jr.** to the board of directors and his appointment as vice president and director of sales has been announced by Wales-Strippit Corp., North Tonawanda, N. Y. Mr. Gray joined the company in 1945 as assistant chief engineer and within a short time was promoted to chief

engineer. He has been associated with the sales department since 1947.

David C. Wycoff has been named manager of the product adaptation department of Clark Controller Co., Cleveland. He was formerly manager of the company's experimental laboratory.

Administrative engineer for the last two years, **J. N. Wolfram** has been appointed engineering manager by the Parker Appliance Co., Cleveland. He joined the company in 1932 as a draftsman.

Robert B. Battersby has been promoted from chief engineer to manager of the Thermosetting Div. of Auburn Button Works Inc., Auburn, N. Y.

Alois Berny Essex recently was appointed administrative engineer by Ford Instrument Co. division of Sperry Rand Corp., Long Island City, N. Y. Mr. Essex has been associated with the division since 1933.

Elliott Co., Jeannette, Pa., has announced the appointment of **Capt. Max Schreiner** (U.S.N., ret.) as executive engineer. He is responsible for all engineering of the company's turbine, compressor, supercharger, and general apparatus divisions.

Charles W. Barbour has joined Phebco Inc., Baltimore, as vice president of engineering. He was formerly assistant chief engineer at Teletronics Laboratory, Long Island, N. Y.

Joseph Modrovsky-Modrey has been named head of the department of mechanical engineering at Union College, Schenectady, N. Y. He was formerly professor of mechanical engineering and head of the machine design section at the Polytechnic Institute of Brooklyn.

Ray Fortune, formerly assistant research director, has been appointed director of development engineering by the Standard Register Co., Dayton, O.

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Is this the kind of stability you want for **PLASTIC PARTS?**

Here is a high-strength development in phenolic molding material for parts in which dimensional stability is critical . . . Durez 16221 Natural. Could it solve problems for you by bringing important benefits of plastics into new product-improving applications?

Durez 16221 Natural simplifies design. Parts conform to mold dimensions with 100% precision. Dimensional change after 1 year at room temperature at 50% relative humidity is .0001%. After 1 year at 100°C., change is .001%.

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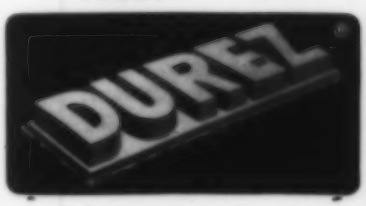

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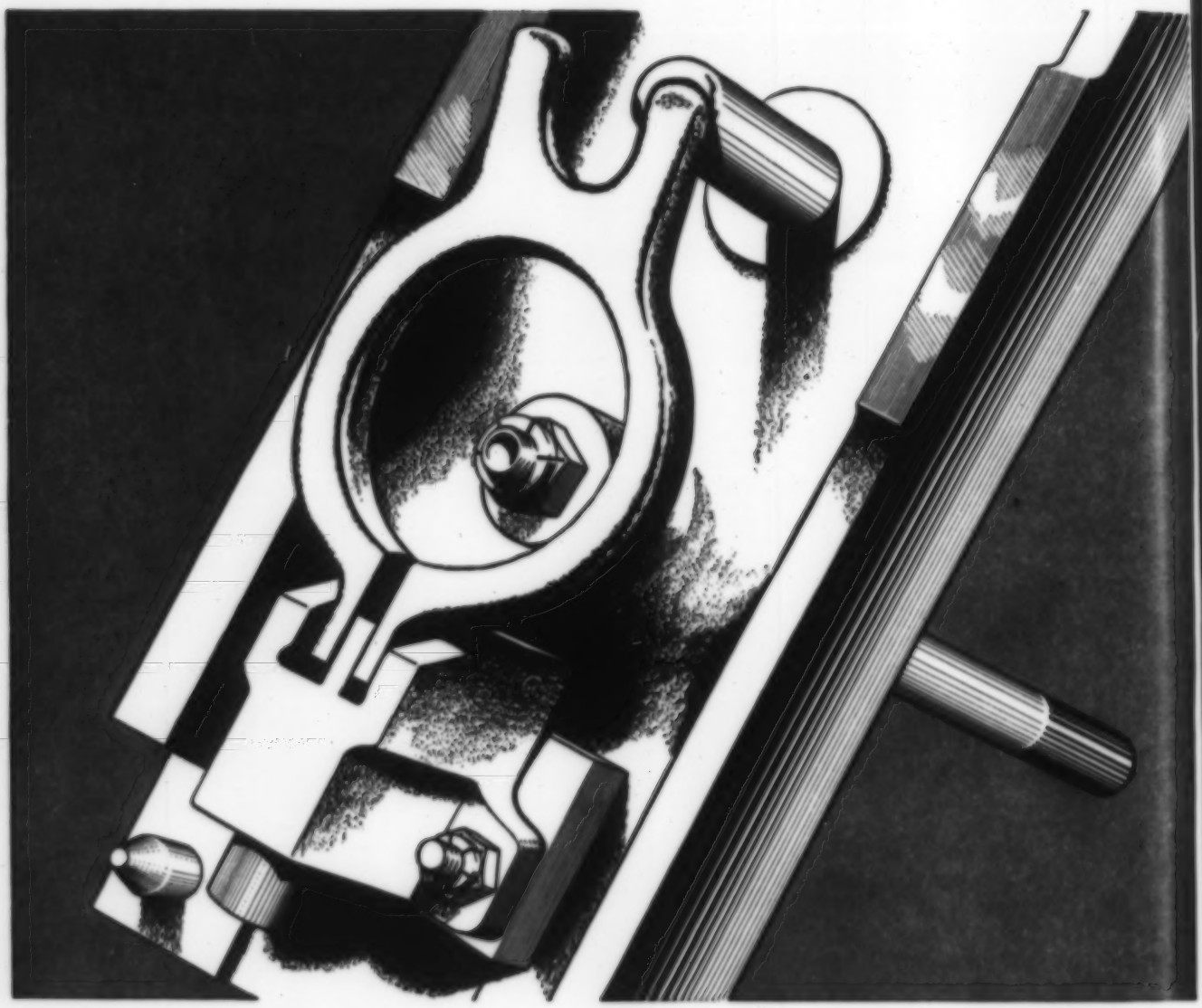
FLEXLOC AT WORK



MORE AND MORE FLEXLOC LOCKNUTS are being used on assemblies where dependable locking is essential to the operating efficiency of the equipment. This stationary spindle is a good example of the difficult jobs FLEXLOC locknuts are doing throughout industry.

FLEXLOCS were put on this unit after a number of other locknuts had failed to keep the spindles tight. Even the high humidity, extreme vibration, and presence of lint and grease have not loosened the FLEXLOCS.

FLEXLOC Self-Locking Nuts—one piece, all metal—are available in a full range of sizes in any quantity. Standard FLEXLOCS are stocked by leading industrial distributors everywhere. Write for Bulletin 866 and samples. STANDARD PRESSED STEEL CO., Jenkintown 18, Pa.

DO YOU KNOW? Standard FLEXLOCS smooth off rough bolt threads. The locking threads on all-metal FLEXLOCS are not chewed up when used on rough bolts.

Standard FLEXLOCS lock securely on bolts varying in diameter tolerances. The all-metal, resilient locking sections of the nut accommodate themselves to the diameter tolerances.

Standard FLEXLOCS are one piece, all metal. They are not affected by temperatures to 550°F. Nuts lacking these features have a more restricted temperature range.

Standard FLEXLOCS lock securely—stopped or seated—when 1½ threads of a standard bolt are past the top of the nut.

Standard FLEXLOCS are not affected by moisture, oil, dirt or grit. They lock efficiently under all conditions, regardless of the vibration encountered.

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LOCKNUT DIVISION

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JENKINTOWN PENNSYLVANIA

MACHINE DESIGN
NOVEMBER 1955

Our New Model in 1956

IN FOUR years the number of editorial pages in MACHINE DESIGN has increased forty-six per cent. We take no particular pride in this statistic, for it is simply a reflection of the phenomenal growth of the design engineering function. Factors influencing this growth are:

1. Engineered products are becoming increasingly complex.
2. Expansion of the national economy is stepping up the demand for machines to perform countless tasks in our modern civilization.
3. As a consequence of increased complexity and volume, more engineers are now active in design.

Many of the problems now facing design engineers can no longer be answered in short articles. At the same time both the complexity and the high activity in design have broadened the scope of our field. More design engineers doing more things give us more developments on which to report.

It all adds up to irresistible pressure for more editorial pages. The editors have attempted to save space, and readers' time, by paring articles to the bone, by adopting various graphical devices to aid readability, by tightening up on acceptance standards, etc., but the limit is being reached.

Permitting the issue to grow in number of pages has a major disadvantage. It creates a rather formidable package — a book the size of a substantial textbook every month. To derive adequate benefit the reader must sift the information he needs from almost four hundred pages. He may have to relinquish the magazine to the next man on the routing slip before he has completely finished. That is happening today.

MACHINE DESIGN's solution is this: Each issue will be slimmed down to a little more than half the current size, but publication frequency will be every two weeks instead of monthly.

We believe that most readers will derive more benefit from sitting down with a smaller magazine more often. Yet with twenty-six issues per year instead of twelve the total volume will be greater, with room for expansion as the field continues to grow.

Our biweekly publication plan goes into effect with the first issue in 1956, to be dated Thursday, January 12. Thereafter we shall publish every other Thursday.

Although this new plan represents a major milestone in MACHINE DESIGN's 26-year history, it is but another step in our continuing program of service to the design engineering profession.

Colin Carmichael

EDITOR

Merit Rating of

By W. Pferd
Mechanical Engineer
Berkeley Heights, N. J.

MERIT rating provides a workable tool for appraising the engineer's performance—a tool which makes that appraisal objective and just through control of such factors as emotion and bias.

A systematic merit rating program provides management with the information necessary to gain the highest engineering quality and performance. Merit rating also provides a firm basis for salary and professional advancement for each engineer. It serves a twofold purpose: for management, it identifies the individual engineer's potential for growth; and for the engineer, it insures fair treatment and recognition for past accomplishments.

Any merit rating program, of course, is not a substitute for intelligent and enlightened personnel relations. But in the one area of evaluating personnel, the same scientific principles and objectivity used in engineering effort can be applied.

Some of the benefits of sound, objective merit ratings are:

They are a basis for helpful counsel between the rater and the ratee. All engineers want to know honestly where they stand, if they are doing good work, and if not, where they should try to improve. The rating information can be used as a firm basis for discussing strong points and weaknesses, and can serve as a means for determining necessary training. The record of capacities and accomplishments embodied in continuous ratings can be used by supervision to determine the filling of special jobs based on previous performance.

Merit rating serves to bring the engineer and his supervisor together. One inherent weakness in large companies is lack of familiarity at higher supervisory levels with the employees. Sporadic verbal reports on employee performance by intermediate levels of supervision can be supplemented by a progressive history and current rating sheet, or top supervision can review all ratings as an operating procedure.

Ratings help to improve supervisor judgment. Snap judgment based on opinions formed during the most recent incident are offset by rating information, which provides a broad picture. The effectiveness of training programs can also be evaluated by supervision in terms of individual growth.

Merit ratings keep employees from being "lost in the shuffle." With a carefully designed rating system, "losing" an employee is difficult. Ratings tend to stimulate confidence in management's fairness; the plan itself is evidence of the attempt by management to be fair and objective. It acts as a stimulant for engineers to improve, since they know they are being rated and are counseled after each rating.

Rating information substitutes fact for fancies. The accumulated ratings filed in personnel records assist management in interdepartmental

Engineers

How to obtain objective evaluation of engineering and job performance by following a planned rating program

RATING SCALE method of judging performance of engineers lists factors to be judged, along with a clear definition of each factor. Rater marks his evaluation on a numerical scale; thus, a numerical total "score" can be obtained. Other types of forms use distinct steps, such as "outstanding," "good," or "poor" to arrive at an overall rating.

MERIT RATING FORM

ENGINEER _____ DEPT. _____

RATER _____ DATE _____

	TRAIT		WELL BELOW AVERAGE	SOMEWHAT BELOW AVERAGE	AVERAGE (Usual)	SOMEWHAT ABOVE AVERAGE (Better than most)	WELL ABOVE AVERAGE (Outstanding)	WEIGHTS	WEIGHTED SCORE
			25 30 35	40 45 50	55 60 65	70 75 80	85 90 95		
1	INITIATIVE	Enterprise; drive; capacity for independent action; degree to which he assumes responsibility when orders are lacking; degree to which he follows through on a job despite obstacles.						1	
2	COOPERATIVENESS	The trait of working whole-heartedly both with and for others in an open-minded objective fashion; possession of the qualities of tact, courtesy, friendliness and tolerance.						1	
3	QUANTITY OF WORK	Amount of useful output in the light of the opportunities afforded by the job. The output may be written or otherwise.						2	
4	QUALITY OF WORK	The general excellence of all kinds of output, including written material, with consideration given to the difficulty of the job. Accuracy, thoroughness and dependability of output should be considered but not quantity. In the case of supervisors, this trait includes skill in directing and guiding men.						2	
5	ORIGINALITY	Creativeness, including imagination and inventiveness.						1	
6	EXPRESSION	Facility in expressing ideas both orally and in writing. This implies the ability to communicate ideas in a logical, coherent fashion and the ability to summarize.						1	
7	ENGINEERING JUDGMENT	Skill in analyzing situations and arriving at sound conclusions even though the available data are incomplete or seemingly contradictory.						1	
8	VERSATILITY - ADAPTABILITY	Capable of doing successfully several lines of work, as need arises.						1	
								Weighted Total	
9	SPECIAL VALUE	This is the place to recognize any special values to the Company which have not adequately been covered in the items above. Examples of Special Values are: Recognition as an expert or authority, extreme inventiveness, unusual contributions to Company prestige, or any unusual ability which contributes to the Company's welfare. Most MTS's will not be cited here.	Cite Special Value here:						*
								Total	

* Score to be assigned at a departmental conference

transfers and serve as a running check on the criteria established by the company for hiring purposes.

Basic Program Considerations

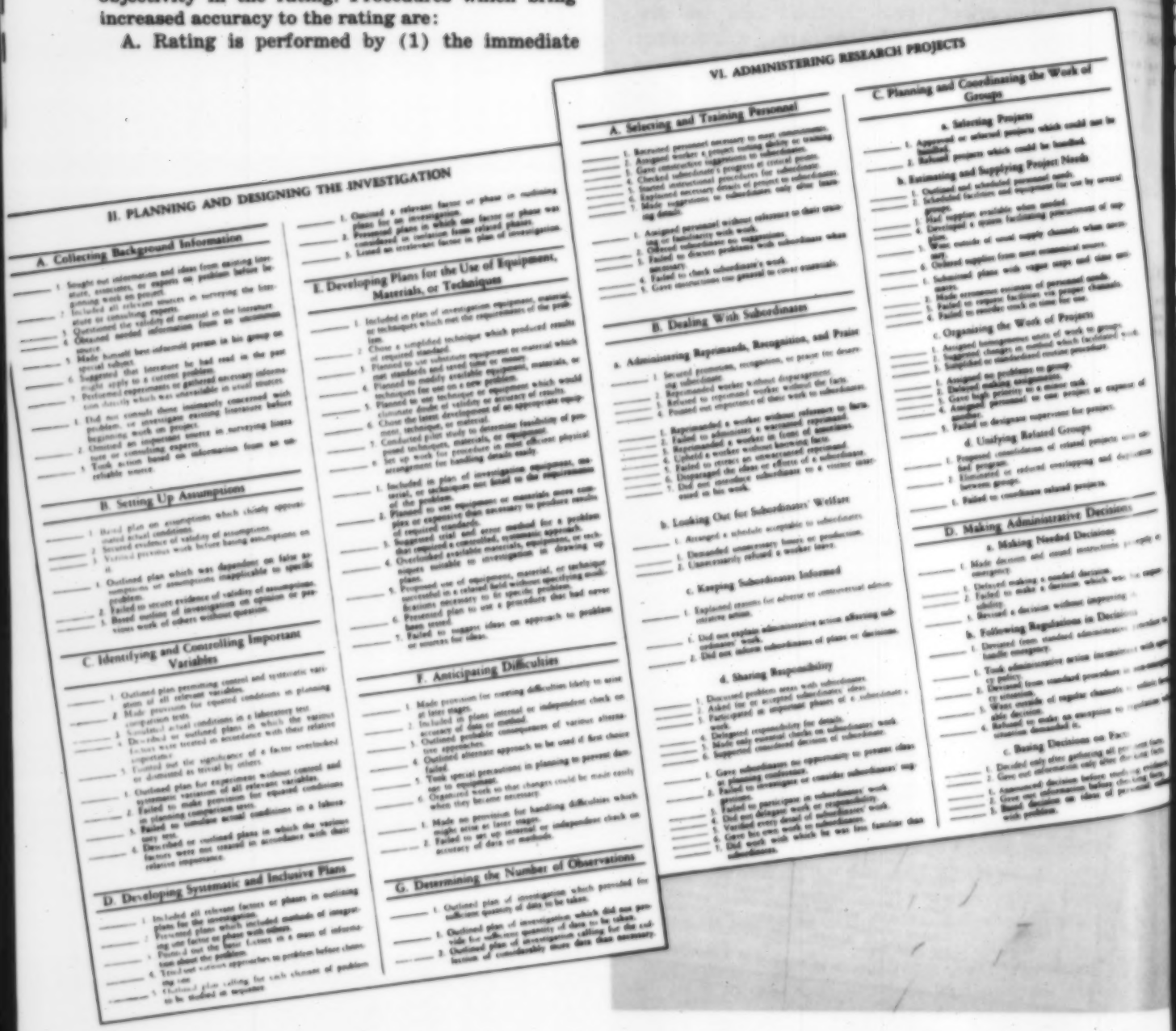
The details involved in carrying out a merit rating program vary from company to company, depending on the qualities each deems most important in its employees. However, all are developed around the resolution of three questions:

1. Who does the rating?
2. How frequently shall rating be done?
3. How shall the rating form be composed?

Junior employees are usually rated by their immediate supervisors. In rating higher-classification employees, such as supervisory personnel, engineers and other professional people, various checks are employed to emphasize accuracy and objectivity in the rating. Procedures which bring increased accuracy to the rating are:

A. Rating is performed by (1) the immediate supervisor, (2) someone over this supervisor, and (3) a company representative who is a member of the personnel department and specifically trained for this job. Ratings are prepared independently by raters 1 and 2 and consolidated in

CRITICAL-INCIDENT FORM supplies the rater with a complete list of factors to be evaluated. This form (only part is shown) was developed by the American Institute of Research for rating research personnel of the Office of Naval Research. The rater checks off the statement which comes closest to describing the performance of the employee. The form can be used to evaluate performance on specific projects.



II. PLANNING AND DESIGNING THE INVESTIGATION

A. Collecting Background Information

1. Sought out information and ideas from existing literature, associates, or experts on problem before beginning work on project.
2. Included all relevant sources in surveying the literature or consulting experts.
3. Questioned the validity of material in the literature.
4. Obtained needed information from an uncommon source.
5. Made himself best-informed person in his group on special subject.
6. Suggested that literature he had read in the past might apply to a current problem.
7. Performed experiments or gathered necessary information directly which was unavailable in usual sources.

1. Did not consult those immediately concerned with problem, or investigate existing literature before beginning work on project.
2. Omitted an important source in surveying literature or consulting experts.
3. Took action based on information from an unreliable source.

B. Setting Up Assumptions

1. Based plan on assumptions which closely approximated actual conditions.
2. Secured evidence of validity of assumptions.
3. Varified premises with before having assumptions on it.

1. Outlined plan which was dependent on false assumptions or assumptions inapplicable to specific problem.
2. Failed to secure evidence of validity of assumptions.
3. Based portion of investigation on opinion or previous work of others without question.

C. Identifying and Controlling Important Variables

1. Outlined plan permitting control and systematic variation of all relevant variables.
2. Made provision for required conditions in planning comparison tests.
3. Included actual conditions in a laboratory test.
4. Described or outlined plans in which the various factors were treated in accordance with their relative importance.
5. Pointed out the significance of a factor overlooked or dismissed as trivial by others.

1. Outlined plan for experiment without control and systematic variation of all relevant variables.
2. Failed to make provision for required conditions in planning comparison tests.
3. Failed to simulate actual conditions in a laboratory test.
4. Described or outlined plans in which the various factors were not treated in accordance with their relative importance.

D. Developing Systematic and Inclusive Plans

1. Included all relevant factors or phases in outlining plans for the investigation.
2. Presented plans which included methods of integrating one factor or phase with others.
3. Pointed out the basic factors or a means of reducing them down the problem.
4. Visualized various approaches to problem before choosing one.
5. Outlined plan calling for each element of problem to be studied or separate

1. Omitted a relevant factor or phase in outlining plans for an investigation.
2. Presented plans in which one factor or phase was considered in isolation from related phases.
3. Leaned on irrelevant factor in plan of investigation.

E. Developing Plans for the Use of Equipment, Materials, or Techniques

1. Included in plan of investigation equipment, material, or techniques which met the requirements of the problem.
2. Chose a simplified technique which produced results of required standard.
3. Planned to use substitute equipment or material which met standards and saved time or money.
4. Planned to modify available equipment, materials, or techniques for use on a new problem.
5. Planned to use technique or equipment which would eliminate doubt of validity or accuracy of results.
6. Chose the latest development of an appropriate equipment, technique, or material.
7. Conducted pilot study to determine feasibility of proposed techniques, materials, or equipment.
8. Set up work for procedure in most efficient physical arrangement for handling details easily.

1. Included in plan of investigation equipment, material, or techniques not found to be the requirements of the problem.
2. Planned to use equipment or materials more complex or expensive than necessary to produce results of required standards.
3. Suggested trial and error method for a problem that required a controlled, systematic approach.
4. Overlooked available materials, equipment, or techniques suitable to investigation in drawing up plans.
5. Proposed use of equipment, material, or technique successful in a related field without specifying modifications necessary to fit specific problem.
6. Presented plan to use a procedure that had never been tested.
7. Failed to suggest ideas on approach to problem or sources for ideas.

F. Anticipating Difficulties

1. Made provision for meeting difficulties likely to arise at later stages.
2. Included in plans internal or independent check on accuracy of data or method.
3. Outlined probable consequences of various alternative approaches.
4. Outlined alternate approach to be used if first choice failed.
5. Took special precautions in planning to prevent damage to equipment.
6. Organized work so that changes could be made easily when they became necessary.

1. Made no provision for handling difficulties which might arise at later stages.
2. Failed to set up internal or independent check on accuracy of data or methods.

G. Determining the Number of Observations

1. Outlined plan of investigation which provided for sufficient quantity of data to be taken.

1. Outlined plan of investigation which did not provide for sufficient quantity of data to be taken.
2. Outlined plan of investigation calling for the collection of considerably more data than necessary.

VI. ADMINISTERING RESEARCH PROJECTS

A. Selecting and Training Personnel

1. Recruited personnel necessary to meet commitments.
2. Assigned worker a project suiting ability or training.
3. Gave constructive suggestions to subordinates.
4. Checked subordinate's progress at critical points.
5. Started instructional procedures for subordinates.
6. Explained necessary details of project to subordinates.
7. Made suggestions to subordinates only after learning details.

1. Assigned personnel without reference to their training or familiarity with work.
2. Offered subordinates no suggestions.
3. Failed to discuss problems with subordinates when necessary.
4. Failed to check subordinate's work.
5. Gave instructions too general to cover materials.

B. Dealing With Subordinates

a. Administering Reprimands, Recognition, and Praise

1. Reprimanded subordinate, or praise for deserving subordinate.
2. Reprimanded worker without disparagement.
3. Refused to reprimand worker without the facts.
4. Praised out importance of their work to subordinates.

1. Reprimanded a worker without reference to facts.
2. Failed to administer a warranted reprimand.
3. Reprimanded a worker in front of associates.
4. Upheld a worker without knowing facts.
5. Failed to correct an unwarranted reprimand.
6. Disparaged the ideas or efforts of a subordinate.
7. Did not introduce subordinate to a visitor concerned in his work.

b. Looking Out for Subordinates' Welfare

1. Arranged a schedule acceptable to subordinates.
2. Demanded unnecessary hours or production.
3. Unnecessarily refused a worker leave.

c. Keeping Subordinates Informed

1. Explained reasons for adverse or controversial administrative action.
2. Did not explain administrative action affecting subordinates' work.
3. Did not inform subordinates of plans or decisions.

d. Sharing Responsibility

1. Discussed problem areas with subordinates.
2. Asked for or accepted subordinates' ideas.
3. Participated in important phases of a subordinate's work.
4. Delegated responsibility for details.
5. Made only essential checks on subordinates' work.
6. Supported considered decisions of subordinates.

1. Gave subordinates no opportunity to present ideas at planning conference.
2. Failed to investigate or consider subordinates' suggestions.
3. Failed to participate in subordinates' work.
4. Did not delegate work or responsibility.
5. Verified every detail of subordinates' work.
6. Gave his own work to subordinates.
7. Did work with which he was less familiar than subordinates.

C. Planning and Coordinating the Work of Groups

a. Selecting Projects

1. Approved or selected projects which could not be handled.
2. Refused projects which could be handled.

b. Estimating and Supplying Project Needs

1. Outlined and scheduled personnel needs.
2. Scheduled facilities and equipment for use by several groups.
3. Had supplies available when needed.
4. Developed a system facilitating procurement of supplies.
5. Drew outside of usual supply channels when necessary.
6. Ordered supplies from most economical source.

1. Submitted plans with vague steps and time estimates.
2. Made erroneous estimates of personnel needs.
3. Failed to request facilities via proper channels.
4. Failed to consider truck in case for use.

c. Organizing the Work of Projects

1. Assigned homogeneous units of work to groups.
2. Suggested changes in method which facilitated work.
3. Subjected or standardized routine procedure.

1. Assigned no problems to group.
2. Delayed making assignments.
3. Gave high priority to a minor task.
4. Assigned personnel to case project at expense of another.
5. Failed to designate supervisor for project.

d. Unifying Related Groups

1. Proposed consolidation of related projects into unified program.
2. Eliminated or reduced overlapping and duplication between groups.

1. Failed to coordinate related projects.

D. Making Administrative Decisions

a. Making Needed Decisions

1. Made decision and issued instructions promptly in emergency.
2. Delayed making a needed decision.
3. Failed to make a decision which was the responsibility.
4. Revised a decision without improving it.

b. Following Regulations in Decisions

1. Deviated from standard administrative procedure to handle emergency.
2. Took administrative action inconsistent with spirit of policy.
3. Deviated from standard procedure in non-routine situation.
4. Refused to make an exception to routine when situation demanded it.

c. Basing Decisions on Facts

1. Decided only after gathering all pertinent facts.
2. Gave out information only after double-checking facts.

1. Announced decisions before checking evidence.
2. Gave out information before checking facts.
3. Based decision on ideas of personal value with problem.

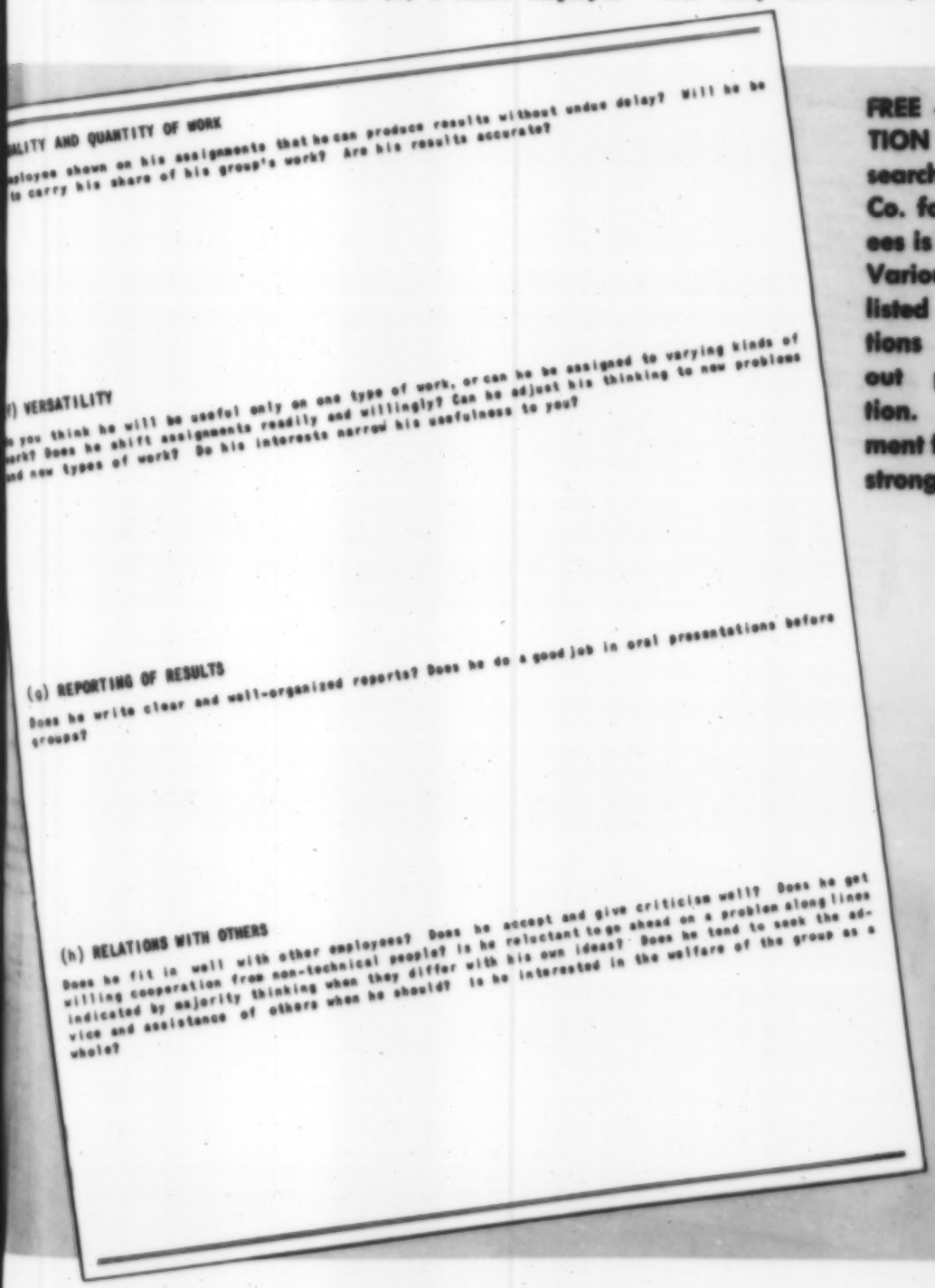
committee with rater 3 acting as chairman. The company representative serves the useful function of judge. By questioning and concluding the information supplied on the two rating sheets, a single report—free from individual halo—is prepared for use in the ratee's department and the personnel department.

B. Rating is performed by (1) the immediate supervisor and (2) a second supervisor on the same level who is familiar with the ratee through personal or work associations. These forms are then reviewed by someone over these supervisors. A single form is prepared by this second-line supervisor with or without the aid of the original raters.

C. Rating is performed by (1) the immediate supervisor, (2) a second supervisor who is familiar with the ratee, and (3) a fellow employee of the ratee. The ratee's immediate supervisor (rater 1), with the approval of his supervisor, chooses the two other people who are asked to rate. The three ratings are than consolidated by second-line supervision or the personnel department.

Merit Rating Methods

Just as there is an attempt to insure objectivity in the rating procedure, numerous rating forms have been developed which are inherently objective. They have been prepared to safeguard rat-



LITY AND QUANTITY OF WORK

ployee shown on his assignments that he can produce results without undue delay? Will he be to carry his share of his group's work? Are his results accurate?

(f) VERSATILITY

e you think he will be useful only on one type of work, or can he be assigned to varying kinds of ork? Does he shift assignments readily and willingly? Can he adjust his thinking to new problems nd new types of work? Do his interests narrow his usefulness to you?

(g) REPORTING OF RESULTS

Does he write clear and well-organized reports? Does he do a good job in oral presentations before groups?

(h) RELATIONS WITH OTHERS

Does he fit in well with other employees? Does he accept and give criticism well? Does he get willing cooperation from non-technical people? Is he reluctant to go ahead on a problem along lines indicated by majority thinking when they differ with his own ideas? Does he tend to seek the advice and assistance of others when he should? Is he interested in the welfare of the group as a whole?

FREE - FORM EVALUATION used by Esso Research and Engineering Co. for technical employees is an essay type form. Various job factors are listed along with questions designed to bring out pertinent information. Rater can comment freely on employee's strong and weak points.

ings from conscious or unconscious bias, injected into the program by the evaluating personnel. The composition of the rating sheet is, in effect, the heart of the rating program. It must be a carefully developed vehicle, which tends to minimize the probability of error inherent in rating. For most companies, it is a thing that has grown with the program.

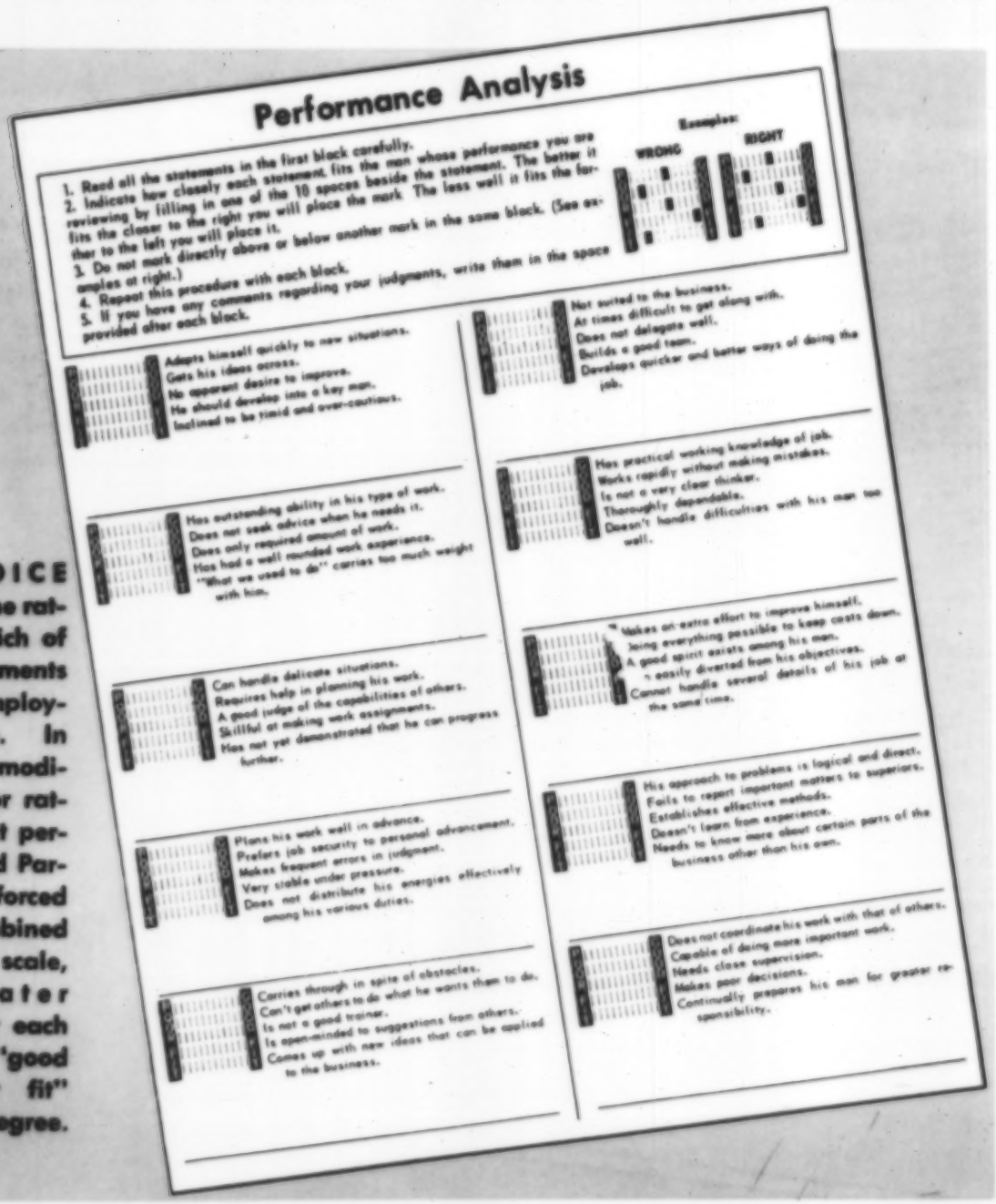
Rating schemes currently used by management in industry fall within the boundaries of six forms:

1. Rating scales
2. Check lists
3. Free-form evaluation
4. Field-review method
5. Forced-choice method
6. Critical-incident method

Many schemes combine two or more of these rating techniques, but ordinarily one predominates.

Rating Scales: This is the most popular form used to evaluate employee performance. The factors to be judged are usually listed with a clear, concise definition, giving to the rater the exact meaning of the factor being considered. For each factor there are distinct steps, such as *outstanding, good* or *poor,* or graduations are obtained by superimposing a numerical scale on the adjective listing. In some forms, the scale is presented by statements which help to further clarify the rating. For the factor *Expression* there might be: "Poor at expressing ideas," then "Ideas not always clearly expressed," proceeding in increasing qualification to "Talented in written and oral expression." When a final adjective or numerical rating of the employee's performance must be obtained, the rating scale form is most satisfactory.

Check lists: In this form, the factors to be

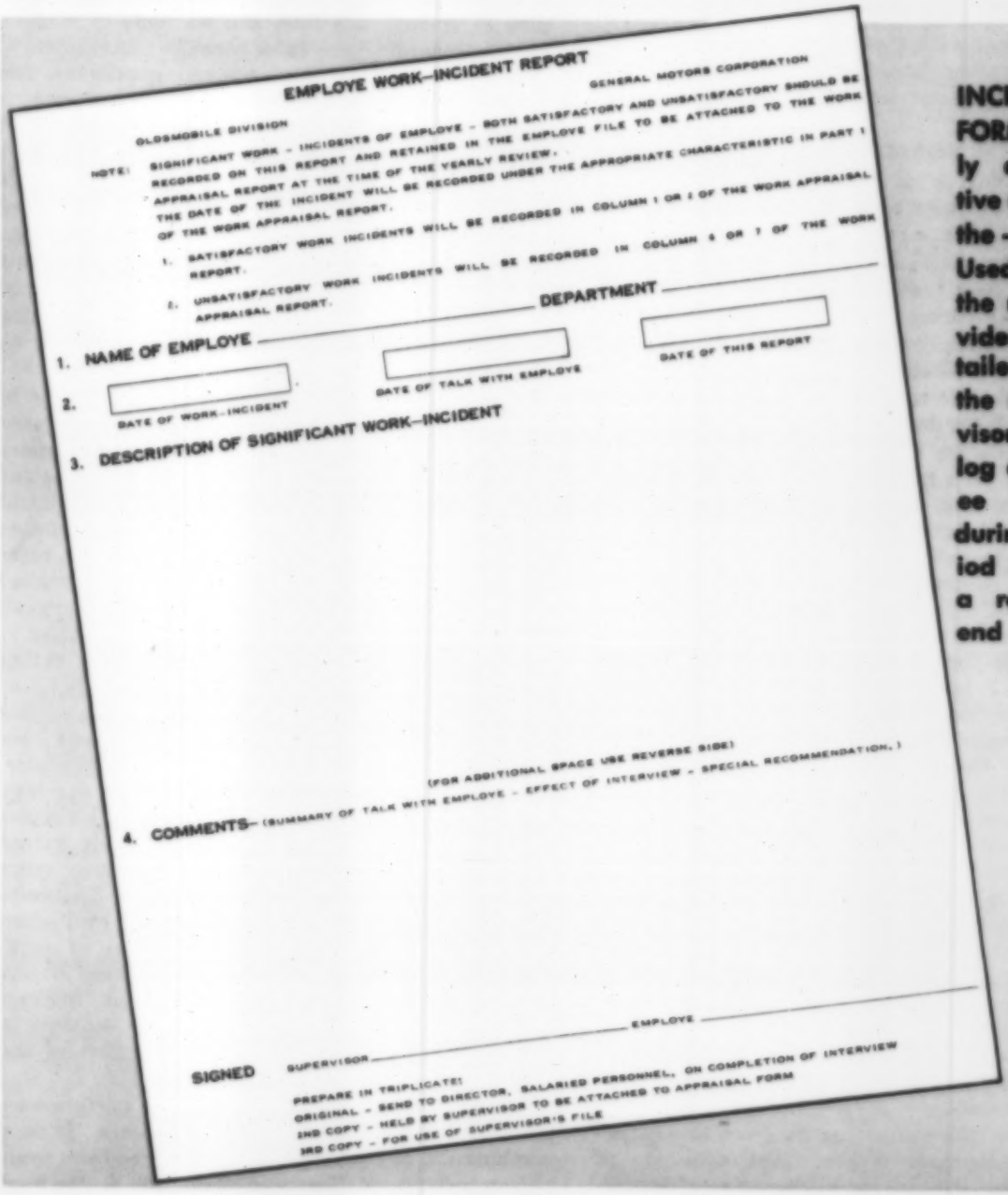

Performance Analysis
1. Read all the statements in the first block carefully.
2. Indicate how closely each statement fits the man whose performance you are reviewing by filling in one of the 10 spaces beside the statement. The better it fits the closer to the right you will place it. The less well it fits the further to the left you will place it.
3. Do not mark directly above or below another mark in the same block. (See examples at right.)
4. Repeat this procedure with each block.
5. If you have any comments regarding your judgments, write them in the space provided after each block.
Examples:
WRONG
RIGHT
Adapts himself quickly to new situations.
Gets his ideas across.
No apparent desire to improve.
He should develop into a key man.
Inclined to be timid and over-cautious.
Not suited to the business.
At times difficult to get along with.
Does not delegate well.
Builds a good team.
Develops quicker and better ways of doing the job.
Has outstanding ability in his type of work.
Does not seek advice when he needs it.
Does only required amount of work.
Has had a well rounded work experience.
"What we used to do" carries too much weight with him.
Has practical working knowledge of job.
Works rapidly without making mistakes.
Is not a very clear thinker.
Thoroughly dependable.
Doesn't handle difficulties with his men too well.
Can handle delicate situations.
Requires help in planning his work.
A good judge of the capabilities of others.
Skillful at making work assignments.
Has not yet demonstrated that he can progress further.
Makes an extra effort to improve himself.
Saving everything possible to keep costs down.
A good spirit exists among his men.
Is easily diverted from his objectives.
Cannot handle several details of his job at the same time.
Plans his work well in advance.
Prefers job security to personal advancement.
Makes frequent errors in judgment.
Very stable under pressure.
Does not distribute his energies effectively among his various duties.
His approach to problems is logical and direct.
Fails to report important matters to superiors.
Establishes effective methods.
Doesn't learn from experience.
Needs to know more about certain parts of the business other than his own.
Carries through in spite of obstacles.
Can't get others to do what he wants them to do.
Is not a good trainer.
Is open-minded to suggestions from others.
Comes up with new ideas that can be applied to the business.
Does not coordinate his work with that of others.
Capable of doing more important work.
Needs close supervision.
Makes poor decisions.
Continually prepares his men for greater responsibility.

FORCED - CHOICE FORM requires the rater to decide which of several statements best describes employee performance. In this particular modification, used for rating management personnel by United Parcel Service, the forced choice is combined with a rating scale, so that the rater decides whether each statement is a "good fit" or "poor fit" and to what degree.

evaluated are listed in broad headings. Each factor is then subdivided into various aspects, and the rater is required to indicate next to each aspect a symbol, adjective, or number representing his evaluation of the employee on that item. For the factor *Knowledge of Job,* such items as *Products, Company Policies* and *Methods of His Job* could be evaluated. This form is also well-suited for arriving at a final rating score, numerical weighting being assigned to the evaluation of each item.

Free-Form Evaluation: This is an essay form which enables the supervisor to comment freely on the employee's strong and weak points. His report may be guided by management in evaluating certain specified factors, or he may be free to report on those factors which he feels are pertinent to the ratee. The form is subjective in nature and, therefore, requires a high degree of intelligence on the part of the rater. Unless certain precautions are taken, its strict interpretation is in reality an evaluation of the rater's ability to express his thoughts regarding the ratee. The form can be strengthened by carefully defining the factors to be rated, by training the raters, by follow-up interviews, and by using rating committees to evaluate and co-ordinate ratings throughout the company.

The free-form report can provide specific information regarding the factors management wishes to evaluate, and is often used to supplement the rating scale form. The rater is required to



EMPLOYE WORK—INCIDENT REPORT

OLDSMOBILE DIVISION — GENERAL MOTORS CORPORATION

NOTE: SIGNIFICANT WORK - INCIDENTS OF EMPLOYE - BOTH SATISFACTORY AND UNSATISFACTORY SHOULD BE RECORDED ON THIS REPORT AND RETAINED IN THE EMPLOYE FILE TO BE ATTACHED TO THE WORK APPRAISAL REPORT AT THE TIME OF THE YEARLY REVIEW.
THE DATE OF THE INCIDENT WILL BE RECORDED UNDER THE APPROPRIATE CHARACTERISTIC IN PART I OF THE WORK APPRAISAL REPORT.

1. SATISFACTORY WORK INCIDENTS WILL BE RECORDED IN COLUMN 1 OR 2 OF THE WORK APPRAISAL REPORT.
2. UNSATISFACTORY WORK INCIDENTS WILL BE RECORDED IN COLUMN 6 OR 7 OF THE WORK APPRAISAL REPORT.

1. NAME OF EMPLOYE _____ DEPARTMENT _____

2. DATE OF WORK-INCIDENT _____ DATE OF TALK WITH EMPLOYE _____ DATE OF THIS REPORT _____

3. DESCRIPTION OF SIGNIFICANT WORK—INCIDENT

4. COMMENTS—(SUMMARY OF TALK WITH EMPLOYE - EFFECT OF INTERVIEW - SPECIAL RECOMMENDATION.) (FOR ADDITIONAL SPACE USE REVERSE SIDE)

SIGNED SUPERVISOR _____ EMPLOYE _____

PREPARE IN TRIPLICATE!
ORIGINAL - SEND TO DIRECTOR, SALARIED PERSONNEL, ON COMPLETION OF INTERVIEW
2ND COPY - HELD BY SUPERVISOR TO BE ATTACHED TO APPRAISAL FORM
3RD COPY - FOR USE OF SUPERVISOR'S FILE

INCIDENT - REPORT FORM records only especially effective or ineffective on-the-job behavior. Used by Oldsmobile, the record form provides space for a detailed description by the reporting supervisor. A record or log on each employee is maintained during the rating period and is used as a reference at the end of the period.

present tangible information for his rating on each factor being considered. This composite form is used more than any other for rating performance of major executives and professional personnel.

Field-Review Method: In this method, no standardized rating form is used, but a representative from the personnel department consults the supervisor regarding the performance of his employees. Certain designated general inquiries are made and, depending on the supervisor's response, additional questioning ensues to determine specific good points and weaknesses of the employee being evaluated. A record of the interview, prepared by the personnel representative, is usually returned to the supervisor to determine whether it reflects what the supervisor intended to report. No definite numerical rating is possible with this approach, but rather, the formal report is a broad analysis of the supervisor's opinion of the ratee.

Forced-Choice Method: This approach produces the highest degree of objectivity of all rating forms. It is composed of groups consisting of four statements which are pertinent in varying degrees to job performance. Each group of statements contains one item that research has proved to be significant in defining successful performance, one that defines unsuccessful performance, and two that are intermediate.

The rater decides which item is most descriptive and which is least descriptive of the employee. He is forced to analyze the employee critically on the statements in each group, uninfluenced by scoring or final evaluation, since the scoring key is not released to the raters.

This form is unique in that the items can be checked for pertinence by statistical validation among successful company employees. It is by far the most effective means thus far devised for providing a basis for administrative action, such as promotion and layoff, but when interest lies in helping supervision deal with employees, or in counseling employees for their future growth, the use of one of the other forms is recommended.

Critical-Incident Method: This method of evaluating personnel was originally developed specifically for research and engineering employees. Detailed accounts of especially effective and ineffective on-the-job behavior are collected by questionnaires and interviews with all supervisors in the company. In obtaining incidents, respondents are asked to describe in detail the examples of behavior that they identify as critical to the job. The incidents collected in this manner are cataloged in similar behavior groupings, for reference by the raters.

In operation, the evaluating program is continuous. Each supervisor makes dated notations of a particular listed behavior whenever a critical incident of this type appears during work association with the employee. This record or log of critical incidents is maintained during the rating period and is used as a reference in rating the employee at the end of the period.

The application of the critical-incident method of employee evaluation for any company is obviously a major undertaking. Its use can only be justified when there is a relatively large number of employees doing similar work which is fundamentally important to the welfare of the company.

Setting Up a Program

All rating forms used to evaluate employees attempt by various means to make the act of rating objective, and attempt to provide concrete information regarding the ratees' status. After exercising care as to who will rate, and on what type form, factors regarding the rater must be considered.

Results obtained from any rating program can be no better than the judgment, honesty and fairness exercised by those who rate. The greatest source of danger is the emotional bias of the rater; his feelings regarding his inadequacy to make appraisals, feeling of doubt as to the principle of rating, feeling of suspicion as to what may happen to him or concern over what might happen to his people as a result of the ratings—all these tend to produce inaccuracy and inconsistency in rating programs. These factors can only be mitigated by constant surveillance of the rating program.

Installation of any evaluating scheme should be done progressively, with liberal education for the raters in the mechanics of rating employees under the system. A raters' manual which indicates the purposes of the system, who will participate and maintain it, and which has sample forms and aids to effective rating, should be prepared for rater use. These things coupled with some centralized control to maintain company-wide consistency all tend to make the rating program more effective.

Scientific personnel evaluation or merit rating of junior grades of employees is an accepted tool of enlightened industrial management. Use of this tool in evaluating engineering personnel has been adopted by many larger manufacturing companies.

General Electric Co., for example, has operated a centralized evaluation program which embraces all employees. The composition of their rating forms is keyed to the grade of employee being rated. In evaluating their engineers, a composite of rating scale, check list and free-form evaluation is employed. Four main headings—value of work, capacity for future growth, aptitude and leadership, and personal traits—are considered. Instructions for the rater on how and what to consider in rating under each heading are also a part of the form.

Wright Aeronautical Co. employs a performance form for evaluating their test engineers. It is a combination of the rating scale and free-form evaluation techniques. Engineer evaluation is also used

by departments of the Bell Telephone Laboratories. The merit rating form used is predominantly the rating scale type.

In comparing the engineering qualification factors considered by these companies, certain specific items appear on all three forms. Initiative, ability to co-operate, expression, and productiveness are apparently of universal importance, since all three companies rate their engineers on these factors. Other factors considered on one or two forms are experience, originality, cost and expense consciousness, accuracy, neatness, quality of work, analytical ability, dependability, technical and special ability, and thoroughness. This is by no means a complete list of those adjectives which define engineering.

The wide variety of items rated on these particular forms serves to point out that each individual company must thoroughly analyze its own engineering requirements for the formulation of factors to be considered on its merit rating form. The factors selected are usually those considered most important by first-line supervision. Factors finally adopted should be pertinent to "on-the-job" performance and should be those in which employees were found to differ most from each other. Ample instruction of the raters regarding understanding of each of the factors and the preparation of a rating manual should be a part of the program.

Use of the selected rating factors on a rating scale form, with space for free-form comments regarding each of the factors, is generally recommended as most satisfactory.

Unless extreme caution is exercised by the rater, periodic rating of employees will result in evaluation based on impressions gained during a later portion of the review period. To avoid the human failing of having impressions tempered by time, it is recommended that work sheets be available to be used by the rater during the rating period for recording pertinent incidents. Where justified, the critical-incident method of continuous rating should be applied.

These recommended features of merit rating, motivated by the sincere attempt by all who rate to exercise objective judgment, can result in an equitable solution to the ever-present problem of engineer evaluation.

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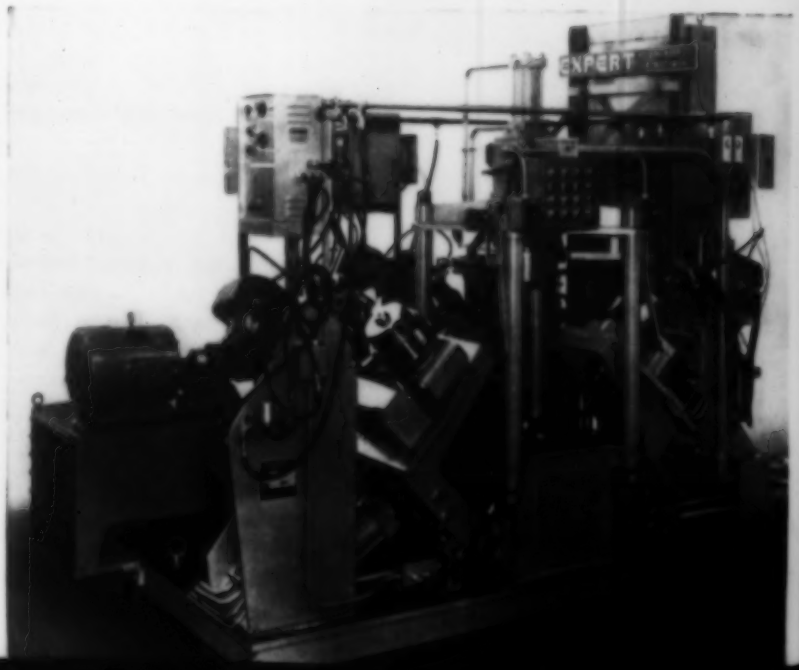
Contemporary Design

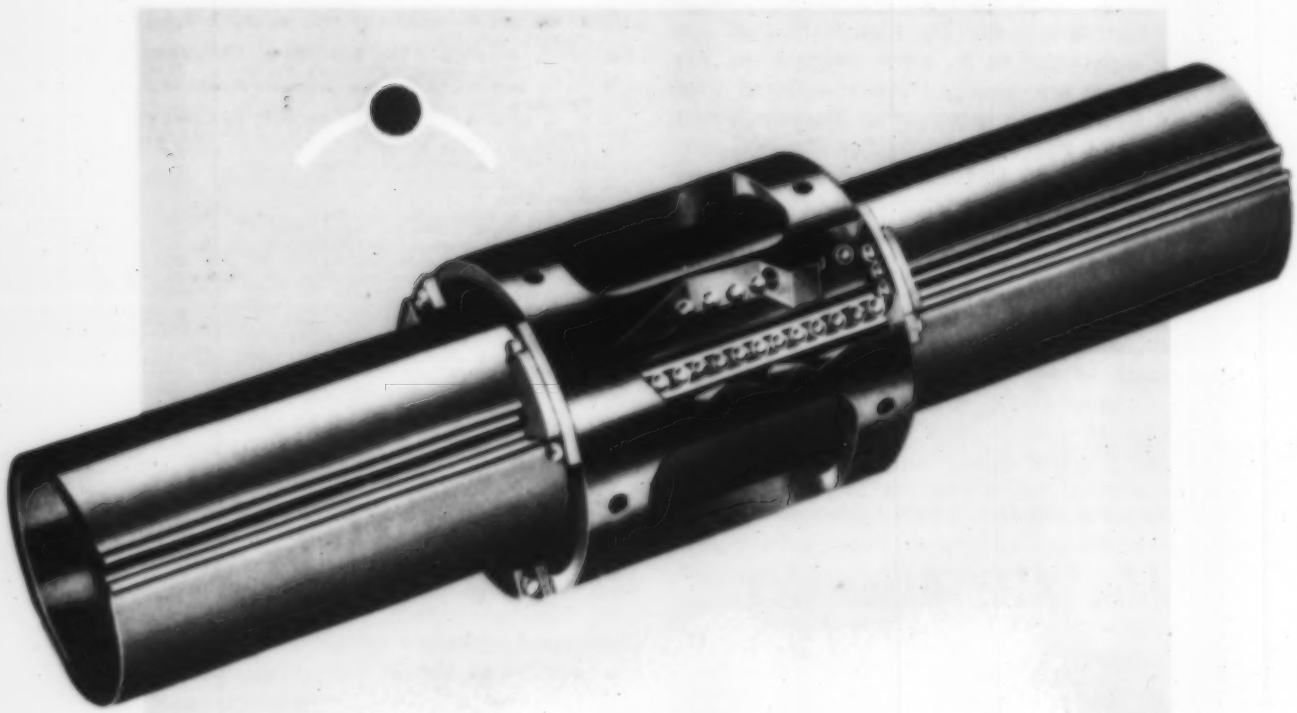
Welder Also Assembles

A NEW welding machine combines assembly and argon shielded-arc welding operations. Called the Expert Triaxial Welder, the machine consists of a vertical hydraulic assembly press and three standard argon shielded-arc welding heads. The welding heads are positioned at 90-degree locations around the assembly press. High production rates are achieved by performing the welding operation on two fixtures while parts are being assembled in a third fixture by the press. To accomplish this, three automation devices transfer the fixtured and assembled part to the welding head, rotate the fixture and part at a speed of 90 inches per minute for the welding operation, and return the fixture and part to pressing position for unloading.

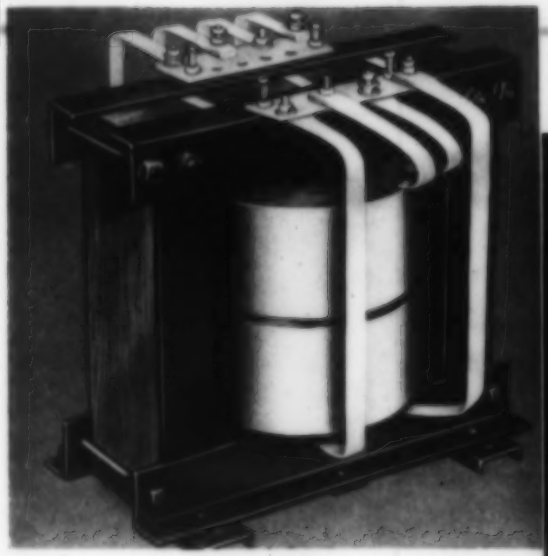
Hydraulically controlled pivoted fixtures provide the required transfer and rotation movements. The three fixtures are pivoted at the base of the press. Individual hydraulic cylinders control the motion of the fixtures in and out of the press. Hydraulic motors rotate the assembled part and fixture as a unit during the welding operation.



scanning the field for Ideas

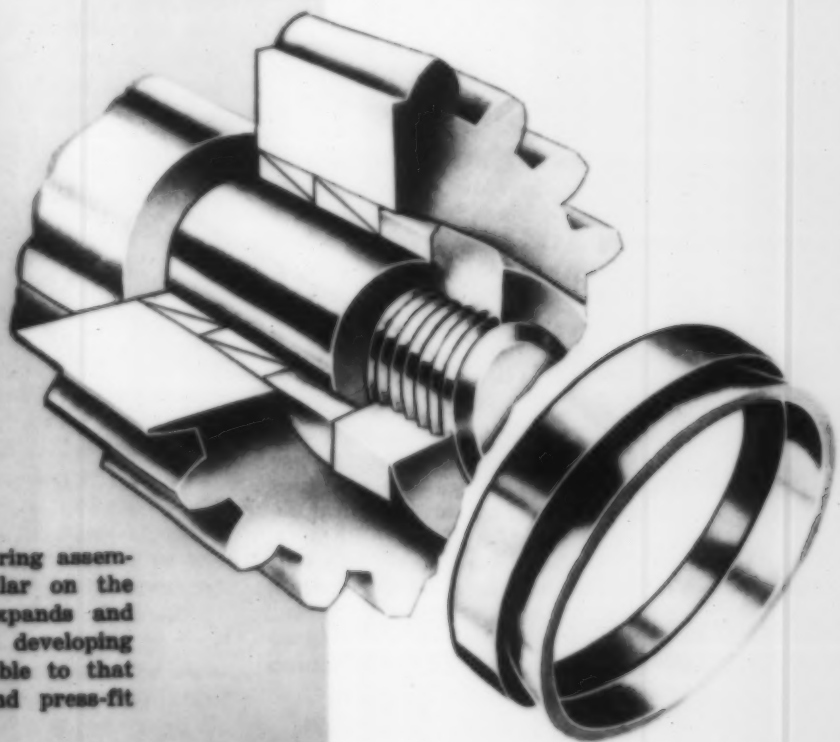


BALL-BEARING SPLINES minimize frictional resistance to linear movement in shaft power connections under high-torque loads. Developed by Saginaw Steering Gear Div., General Motors Corp., the spline design is in principle a ball-bearing screw with infinite lead. Torque transmission between the shaft and the external "nut" member is accomplished by means of balls mounted in mating bearing races in the two members. Relative linear motion of the two members is facilitated by the rolling action of the bearing balls which are recirculated continuously along the races through independent closed circuits. A ball-return guide in the external nut member interrupts the path of the balls, deflects them from the race, and guides them through the body of the member and back to the race.



OXIDE INSULATING FILMS provide an effective means of electrically separating metal conductors. The principle, as reported by Reynolds Metals Co., is based upon a special anodizing process which creates an insulation coating (0.002-in. thick) on strips of aluminum foil or thin aluminum sheets. Employed as electric coil windings, the anodized strips eliminate the need for conventional insulating materials and provide a compact coil construction capable of operating at high temperatures with good heat dissipation factors.

SECURE LOCKING of hub-mounted shaft assemblies is accomplished without keyways or setscrews by a novel expanding ring construction. Originally developed in Germany and manufactured in the United States by the U. S. Automatic Corp., the Gripspring utilizes mating pairs of rings, triangular in cross-section, wedged between the hub and shaft under heavy pressure to produce a locking action. As pressure is applied axially to the ring assembly by means of a collar on the shaft, the outer ring expands and the inner ring contracts developing a holding force comparable to that achieved with shrink and press-fit assemblies.



An Easy Way to Make

PERSPECTIVE DRAWINGS

True perspective drawings are better looking than any other type of pictorial engineering drawing. But they are also more difficult to understand and lay out. Here is a practical method for making true perspectives that eliminates most of the usual troubles. No special equipment is needed. Instead, a basic chart is constructed, which can be used over and over again. Construction of the chart is easy, and drawings made with it are accurate and simple to execute.

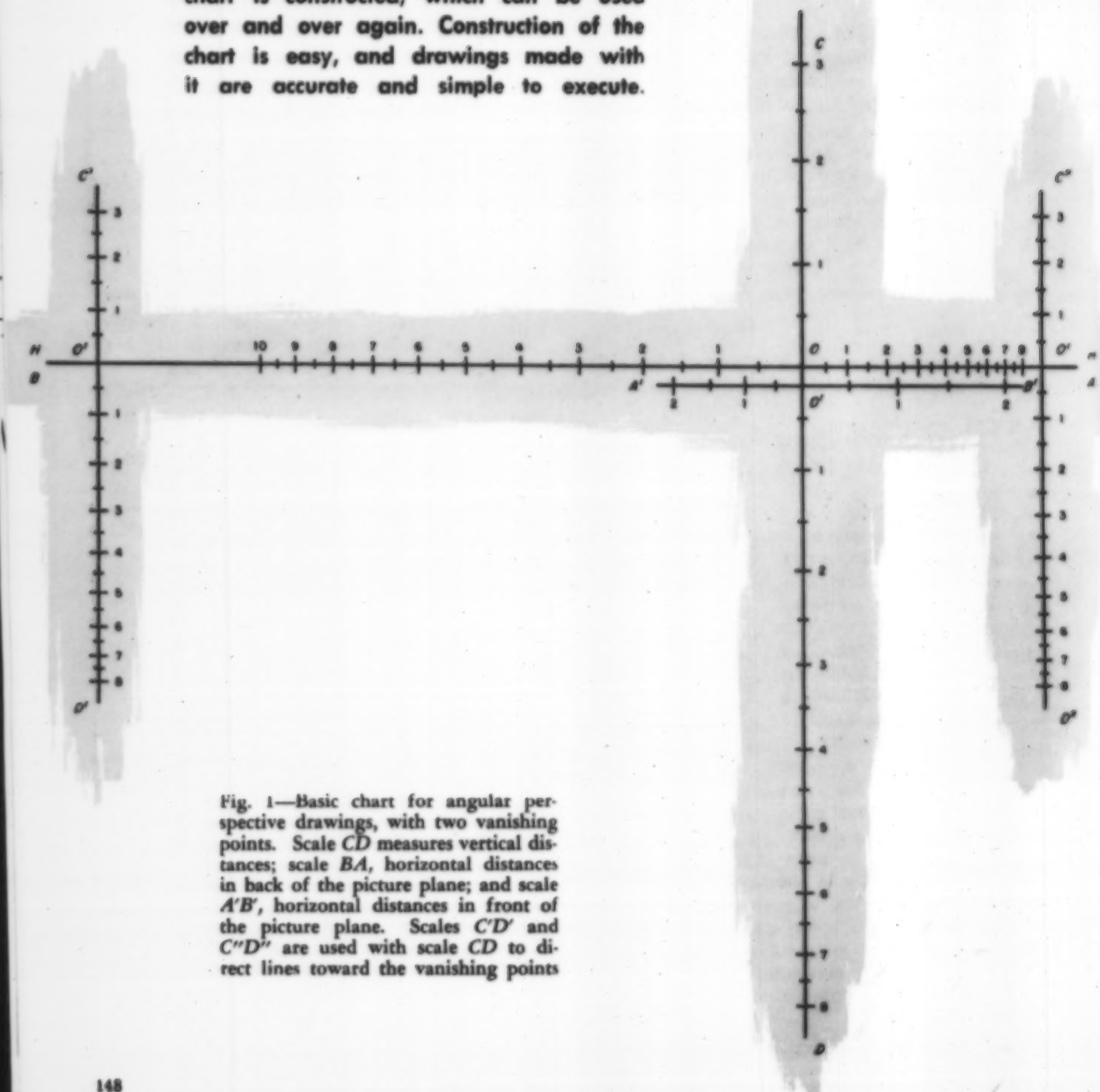
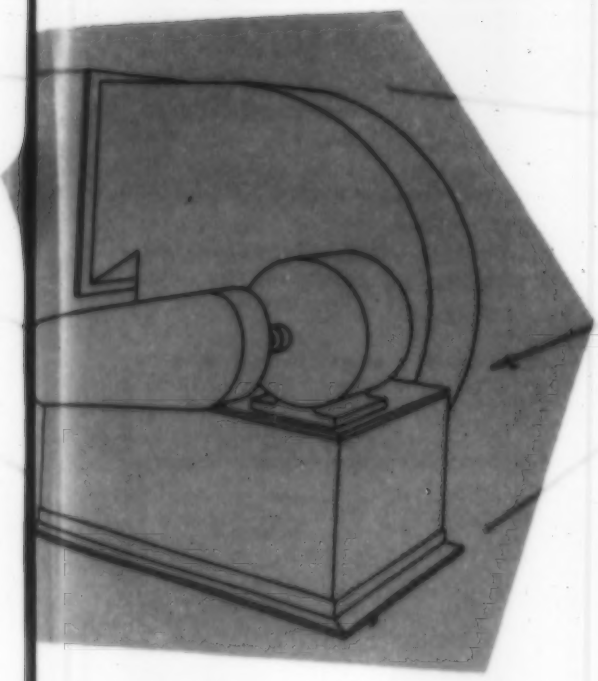


Fig. 1—Basic chart for angular perspective drawings, with two vanishing points. Scale *CD* measures vertical distances; scale *BA*, horizontal distances in back of the picture plane; and scale *A'B'*, horizontal distances in front of the picture plane. Scales *C'D'* and *C''D''* are used with scale *CD* to direct lines toward the vanishing points



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VARIOUS methods have been devised to make perspective drawing easy. Commercial equipment can be obtained, but may not be justified if drawings are made only occasionally. Or some of the simpler, more general methods can be used. These general methods, however, require that vanishing points be determined and that measuring lines and measuring points be located. They require space and are not too well adapted to small boards and areas.

The simple method described here, however, has been developed for use in special work. This method consists of using a chart based on a fixed view distance and fixed angles. Any view distance may be used and any angles, but different angles and distances will require a chart for each variation. This is not too great an inconvenience, since a selection of only two or three basic charts will actually be ample for products in the same general size range. The basic charts can be used over and over if drawings are made on tracing-paper overlays. And, best of all, the work can be kept within the confines of the usual drafting board.

Description of the Basic Charts: The basic type of chart used with angular perspective drawings is shown in *Fig.* 1. Although numerical values are shown on the scales, a large chart must be made for actual use, and to a scale best suited to the objects to be drawn. Several might be prepared for typical situations.

In *Fig.* 1, the vertical line *CD* is in the picture plane directly in front of the view point. The horizon line *HH* is also in the picture plane and intersects the vertical line *CD* at *O*. From point *O*, vertical distances are measured above and below the horizon line *HH*, and horizontal distances are measured to the right and left of vertical line *CD*.

For convenience, scales *OC* and *OD*, which measure vertical distances, are placed on line *CD*. Scales *OA* and *OB*, which measure the part of the pictured object that is behind the picture plane, are placed on the horizon line *HH*. Scales *OA'* and *OB'* are placed below the horizon line *HH* and measure parts of the pictured object that are in front of the picture plane. Auxiliary scales *C"D"* and *C'D'* are placed to the right and to the left of vertical scale *CD*. *These auxiliary scales do not measure anything and are only to determine the direction of lines through the vanishing points.*

Vanishing points are necessary in perspective drawing, but since they are usually off the board on larger drawings, a substitute may be used. On these charts, the substitutes are the auxiliary scales *C'D'* and *C"D"*. These auxiliary scales have a definite relation to the main scale and eliminate the need for vanishing points, since a line drawn through a point of a given numerical value on the main scale and through a point having the same value on the auxiliary scale will also pass through the vanishing point. As mentioned before, the auxiliary scales are not used for measuring purposes, but are simply used as guides for the lines being drawn.

How to Set Up the Basic Charts: A plan of the picture plane and the station point, *Fig.* 2*a* shows the method of locating the vanishing points and the auxiliary scales. First, angles θ and α (which must total 90 degrees) and distance c are selected —by trial and error or from experience. The left vanishing point is located by

$$m = c \tan \theta \quad \ldots\ldots (1)$$

and the right vanishing point by

$$n = c \tan \alpha \quad \ldots\ldots (2)$$

Auxiliary scale *C'D'* may be placed any convenient distance m' to the left of scale *CD*, *Fig.* 2*a*.

Scale dimensions of scale $C'D'$, *Fig.* 2*b*, will correspond to those of scale CD by

$$D' = \frac{m - m'}{m} D \quad \ldots\ldots (3)$$

where D' is the length on $C'D'$ and D is the corresponding length on CD. Thus, if m' is made equal to $\frac{1}{4}m$, scale D' will be $\frac{3}{4}D$; and if m' is made $\frac{3}{4}m$, scale length D' will be $\frac{1}{4}D$.

Similarly, scale dimensions of $C''D''$ are related to those of CD by

$$D'' = \frac{n - n'}{n} D \quad \ldots\ldots (4)$$

where D'' is the scale dimension on $C''D''$. Method of determining D is outlined later.

Points on the drawing scales have a definite relation to the corresponding points on the object.

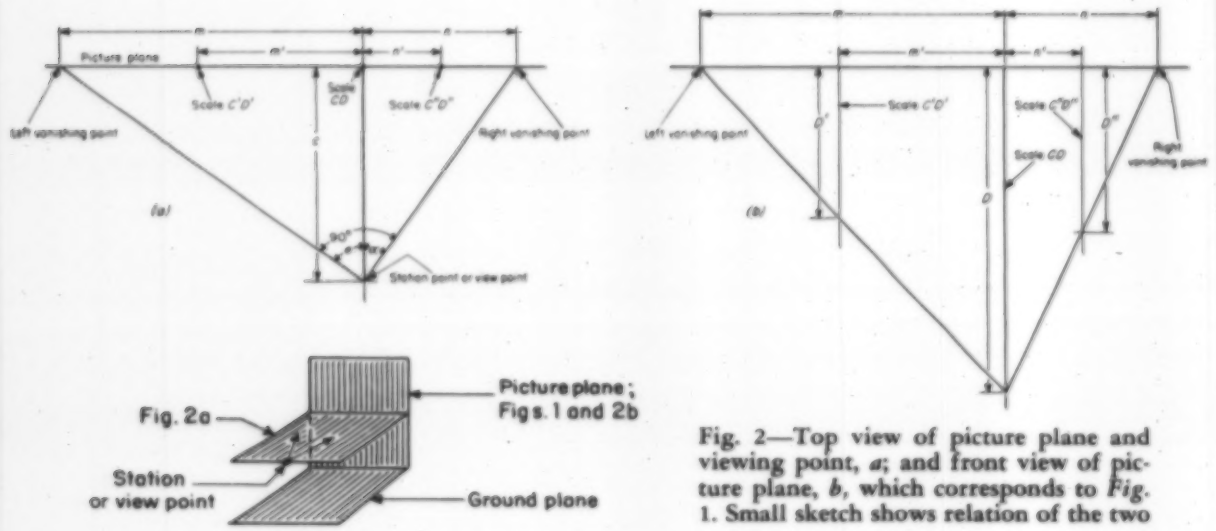


Fig. 2—Top view of picture plane and viewing point, *a*; and front view of picture plane, *b*, which corresponds to *Fig.* 1. Small sketch shows relation of the two

Fig. 3—Top view of left side plane of object, picture plane and station point

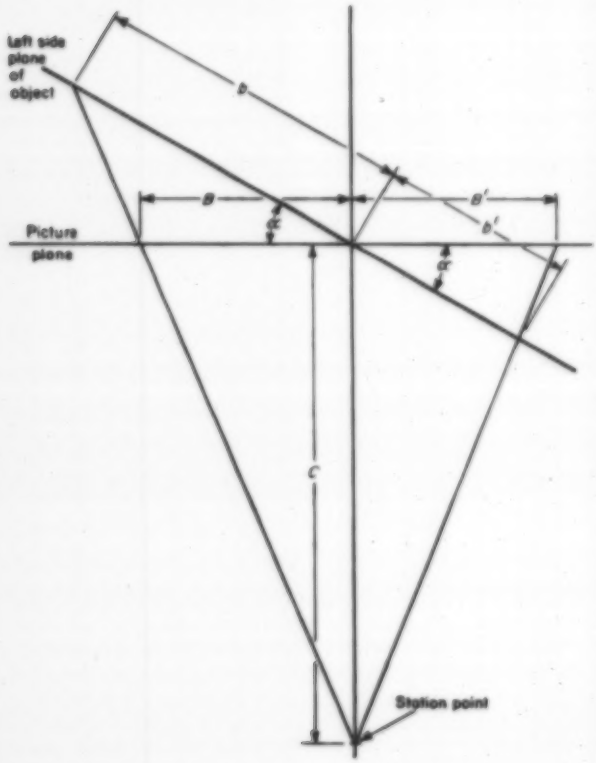
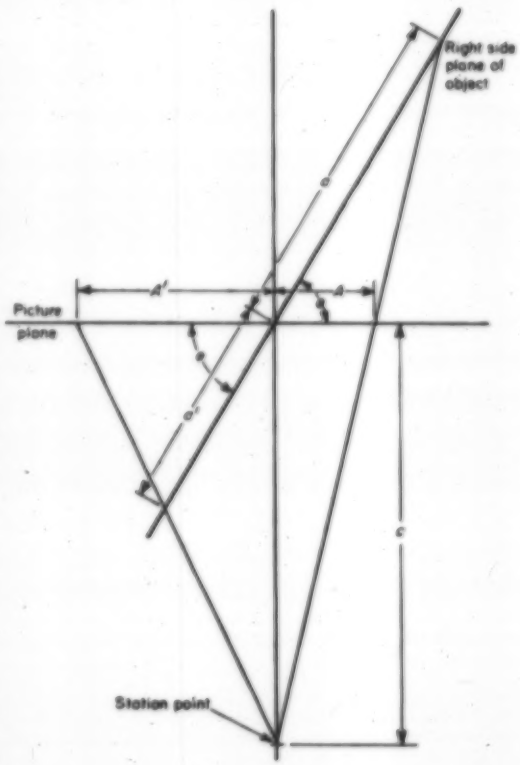


Fig. 4 — Top view of right side plane of object



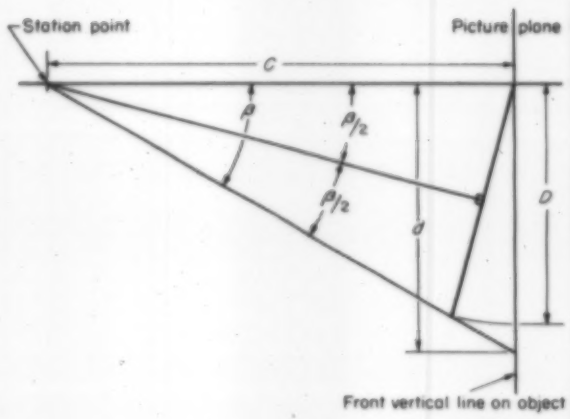
They can be calculated and it will not be necessary to make a large layout to measure them graphically. *Figs.* 3 through 5 show the methods used in calculating the scales.

Method of calculating scales *OB* and *O'B'* (*Fig.* 1) is shown on *Fig.* 3. Dimension *b* measures a line on the object behind the picture plane, which is projected to the picture plane as dimension *B*. From a study of similar triangles,

$$B = \frac{cb \cos a}{c + b \sin a} \quad \ldots\ldots (5)$$

Dimension *B* is used on scale *OB*, *Fig.* 1.

Fig. 5—Side view of object, picture plane and station point



In a similar manner, dimension *b'* measures a line in front of the picture plane, and must be projected as *B'*. From similar triangles,

$$B' = \frac{cb' \cos a}{c - b' \sin a} \quad \ldots\ldots (6)$$

Dimension *B'* is used on scale *OB'*, *Fig.* 1.

Scales *OA* and *O'A'* are calculated in the same way, and the method is shown on *Fig.* 4. Thus,

$$A = \frac{ca \cos \theta}{c + a \sin \theta} \quad \ldots\ldots (7)$$

Dimension *A* is used on scale *OA*, *Fig.* 1. Also

$$A' = \frac{ca' \cos \theta}{c - a' \sin \theta} \quad \ldots\ldots (8)$$

Dimension *A'* is used on scale *OA'*, *Fig.* 1.

The vertical lines of an object cannot be drawn full size, since an object is foreshortened as it is viewed, and the amount of foreshortening increases with the angle and the distance from the viewing point. The method used on *Fig.* 1 to provide foreshortening on the vertical scale *CD* is given by *Fig.* 5. *Fig.* 5 shows the angle and foreshortened dimensions below the horizon, but the same calculated dimensions may also be used above the horizon.

In *Fig.* 5, by constructing the isosceles triangle shown,

$$D = 2c \sqrt{\frac{F - c}{2F}} \quad \ldots\ldots (9)$$

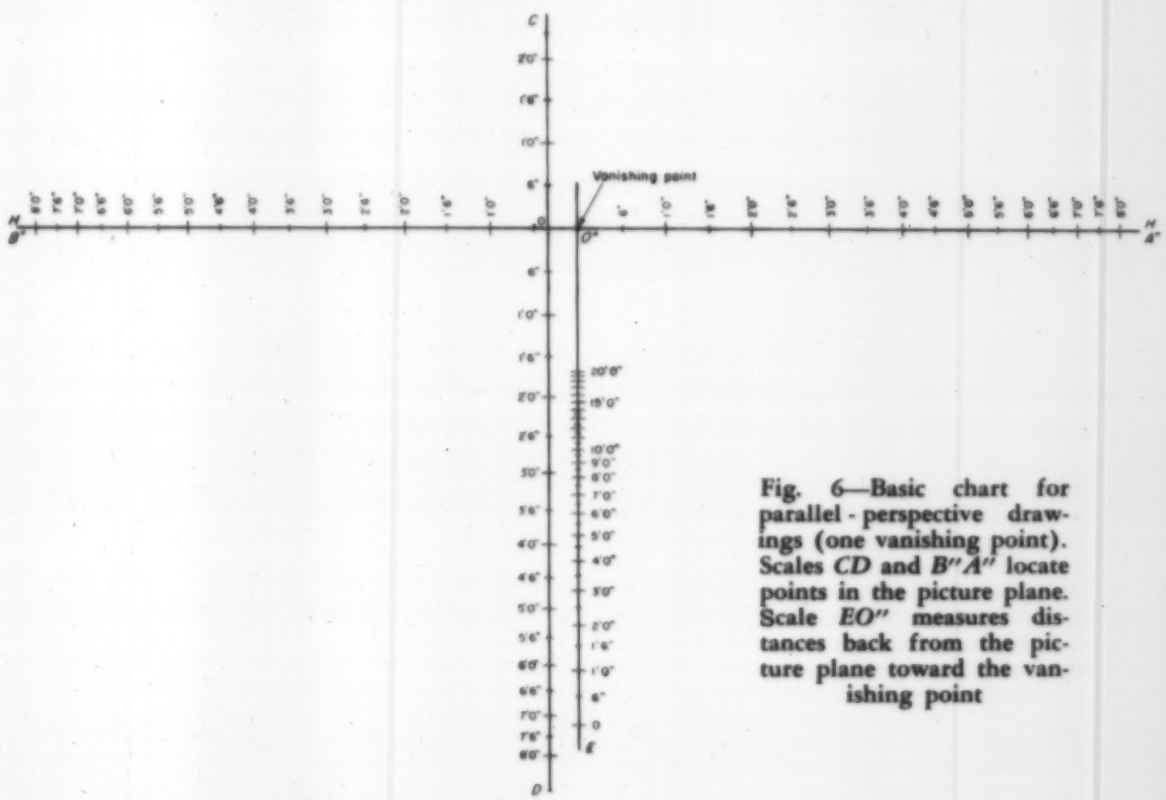


Fig. 6—Basic chart for parallel-perspective drawings (one vanishing point). Scales *CD* and *B''A''* locate points in the picture plane. Scale *EO''* measures distances back from the picture plane toward the vanishing point

where

$$F = \sqrt{c^2 + d^2}$$

Dimension D is used on scales OC and OD, *Fig.* 1.

Setting Up Parallel-Perspective Charts: Some objects appear better if the drawing is made in parallel perspective with one vanishing point.

In *Fig.* 6, the basic chart used for parallel-perspective drawings is shown. As in angular perspective, line CD is a vertical line in the picture plane, and the vertical scale CD is placed on this line. Line HH is the horizon line and, for convenience, scale $B''A''$ is placed on HH. This scale is also in the picture plane.

Since vertical scales CO and OD, and the horizontal scales $B''O''$ and $O''A''$, are all foreshortened, the method shown previously for *Fig.* 5 is used to calculate these scales. Scale EO'' measures the horizontal distance behind the picture plane, and away from the observer toward the horizon. This scale is at ground level and is calculated according to *Fig.* 7.

From *Fig.* 7 and similar triangles,

$$E = \frac{eh}{e + c} \qquad (10)$$

Dimension E is used on scale EO'', *Fig.* 6.

The zero point on scale EO'', *Fig.* 6, is placed below HH a distance equal to h on *Fig.* 7. This distance is the actual distance according to the scale used, and is not measured by scale CD.

Table 1—Values from Equations 5 and 6

b (ft, in.)	B (ft, in.)
0 0	0 0
6	5 1/8
1 0	9 3/4
6	1 2 1/4
2 0	6 3/4
6	10 3/4
3 0	2 2 1/4
6	5 3/4
4 0	9 1/4
6	3 0 1/8
5 0	3 5/8
6	6 7/8
6 0	9 5/8
6	4 0 7/8
7 0	2 5/8
6	5 7/8
8 0	7 5/8
6	9 3/4
9 0	11 3/4
6	5 1 3/4
10 0	3 3/4

b' (ft, in.)	B' (ft, in.)
0 0	0 0
6	5 3/4
1 0	11 7/8
6	1 5 1/8
2 0	11 3/4

Table 2—Values from Equations 7 and 8

a (ft, in.)	A (ft, in.)
0 0	0 0
6	2 3/4
1 0	5 3/4
6	7 3/4
2 0	9 5/8
6	11 3/4
3 0	1 1 3/4
6	3 1/4
4 0	4 3/4
6	6 7/8
5 0	7 3/4
6	8 3/4
6 0	9 3/4
6	10 5/8
7 0	11 5/8
6	2 0 3/4
8 0	1 5/8

a' (ft, in.)	A' (ft, in.)
0 0	0 0
6	3 7/8
1 0	6 3/4
6	10 5/8
2 0	1 3 7/8

Practical Examples of Chart Layout: The preceding description should give enough information to permit the numerical values of the scales to be calculated and placed on the charts. Actual charts corresponding to *Figs.* 1 and 6 may be made any size to suit the objects to be drawn.

Scale layout dimensions obtained from Equations 1 through 6 are in the same units as dimensions on the object being drawn. Thus, they must be modified to bring the drawing down to size. This can be accomplished either by multiplying by an appropriate scale factor (e.g., 1/4 for 3 inches = 1 foot), or by using an engineer's or architect's scale to lay out the charts.

As a practical example, the method used to lay out an angular perspective drawing chart, *Fig.* 1, will be outlined.

First, the angles and fixed distances are selected. Values assigned are a matter of experience or of trial and error. For *Fig.* 1, values selected are:

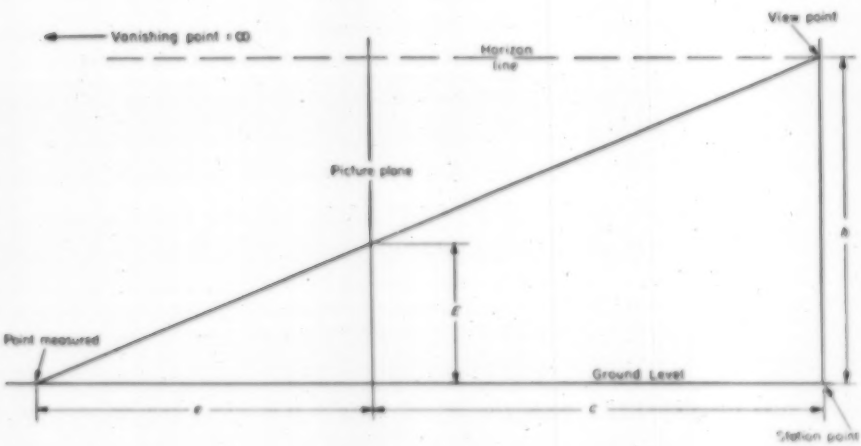


Fig. 7—Side view of picture plane and view point. Vanishing point is at the horizon line or at infinity distance

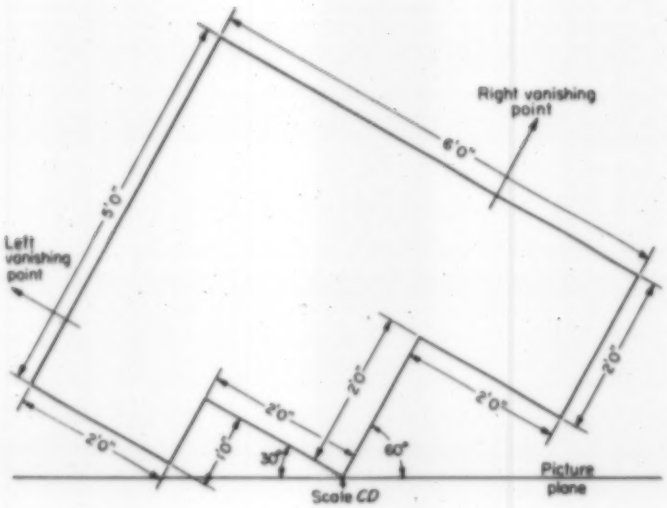
Example 1 —Drawing an Angular Perspective

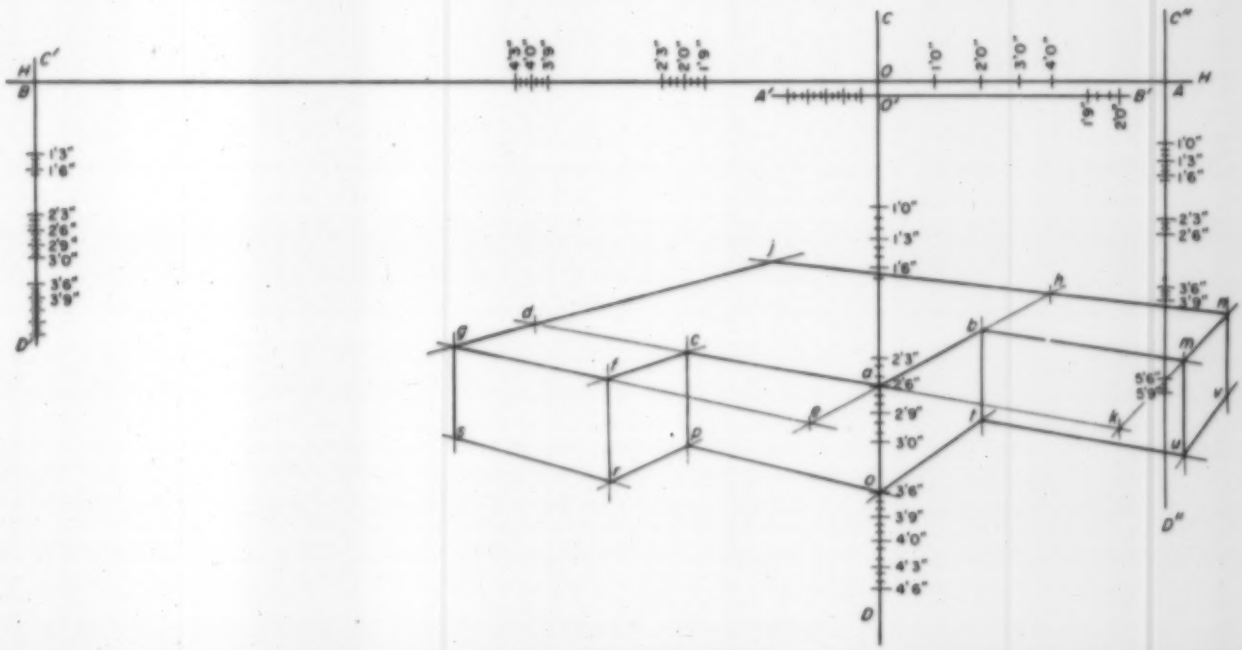
IN making an angular perspective drawing (two vanishing points), three planes must be considered: (1) the picture plane, (2) a vertical plane running through the left vanishing point and intersecting the picture plane at *CD*, and (3) a similar plane running through the right vanishing point with intersection at *CD*.

Vertical distances are all measured on scale *CD*, and these measurements must be projected back or forward from the picture plane. Horizontal distances behind the picture plane are measured on scale *BO* for points lying in the plane through the left vanishing point, or on scale *OA* if in the plane through the right vanishing point. All other points not in these two planes must be located on one of the two planes and projected to their proper positions. Points lying in front of the picture plane are similarly located by scales *O'B'* or *A'O'* for planes passing through the left and right vanishing points, respectively.

Scales *C'D'* and *C"D"* are used to project lines back from scale *CD* toward the vanishing points. A line from any point on scale *CD* through the corresponding point on either scale will pass through the vanishing point.

1. A starting point, *a*, on scale *CD* is chosen. For this example, a point 2 ft 6 in. below the horizon line was selected. Other points would show more or less of the top face.
2. A line *acd* is drawn from 2 ft 6 in. on scale *CD* to the same point on scale *C'D'*.
3. Verticals dropped from scale *AB* determine points *c* and *d*.
4. In a similar matter line *abh*, and points *b* and *h* are located and drawn, using scales *CD* and *C"D"* to determine line directions, and scale *AB* to locate points on these lines.
5. Line *abh* is extended toward *e* (in front of the picture plane).
6. Point *e* is determined by dropping a vertical from scale *A'B'*.
7. Line *efg* is drawn through point *e* by shifting the straightedge to intersect equal distances on scales *CD* and *C'D'*.
8. Line *cf* is drawn through point *c* by the same procedure, using scales *CD* and *C"D"*. This automatically locates point *f* by intersection with *efg*.
9. Line *dj* is located in the same manner through point *d*, using scales *CD* and *C"D"*. Point *g* is thus established by intersection of *dj* and *efg*.
10. Points *k*, *m*, *n* and *j* are determined by exactly the same procedure.
11. Point *o* is located 1 ft below *a*. Points *p*, *r*, *s*, *t*, *u*, and *v* are located vertically below corresponding points on the upper face, on lines through the vanishing points.

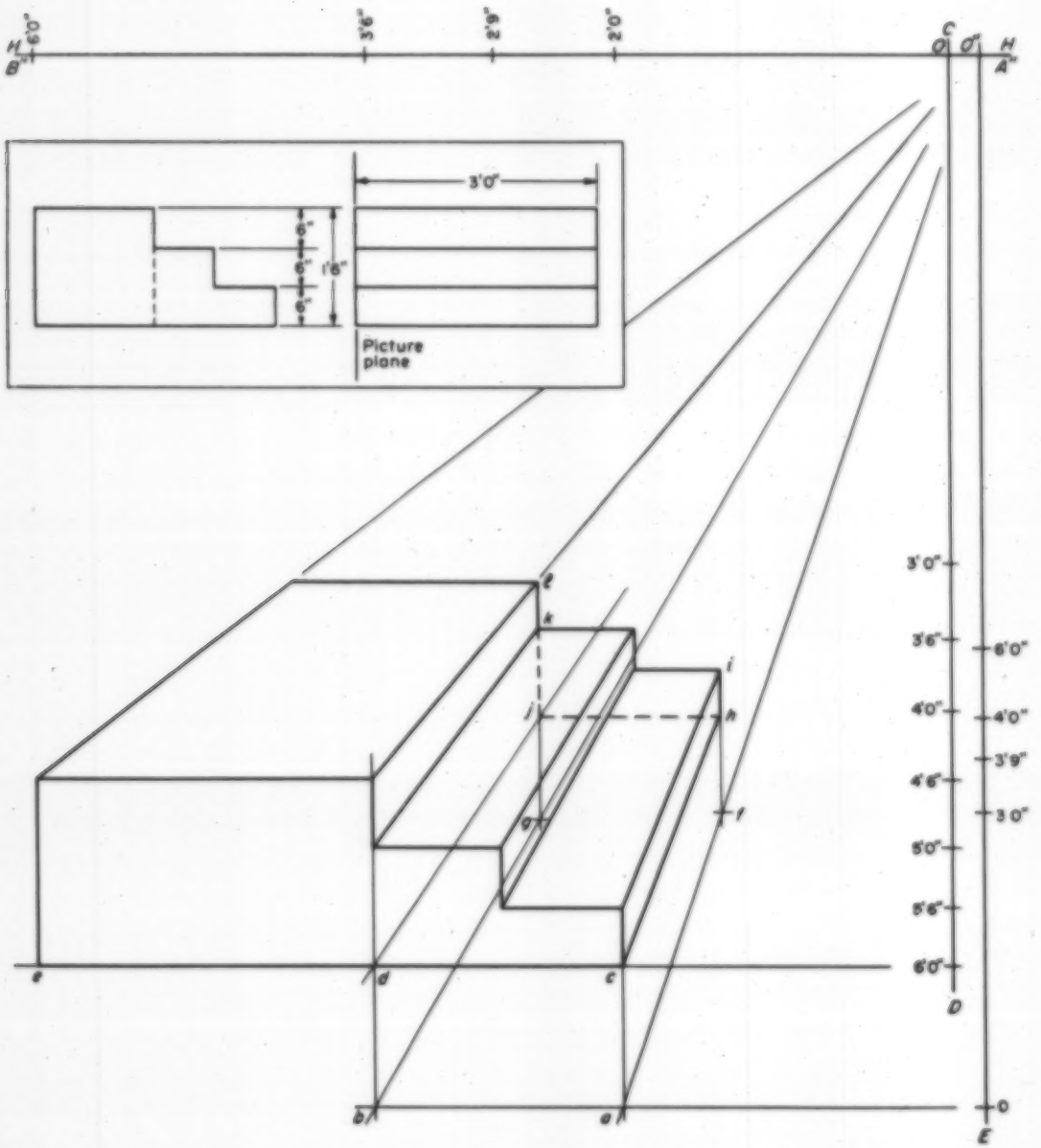




Example 2 —Drawing a Parallel Perspective

FOR a parallel-perspective drawing (one vanishing point), the whole object is drawn behind the picture plane. Points on the picture plane are located by using scales *B"A"* and *CD*, and points located behind the picture plane toward the vanishing point are measured back from the picture plane toward *O"*. All distances behind the picture plane are measured from the zero point on scale *EO"*, which is in the picture plane.

1. For the best view, the lower left quadrant of the chart is selected.
2. Bottom of the object is located at 6 ft below the horizon line as measured on scale *CD*.
3. Line *ab* is drawn to the left from the zero point on scale *EO"*.
4. Point *c* is located at any position desired on scale *B" A"*, and points *d* and *e* are then located.
5. Front face of the object (in the picture plane) is drawn by use of points *c*, *d* and *e*, and measurements from scales *CD* and *B" A"*.
6. Verticals are dropped from *c* to locate *a* and from *d* to *b*. Lines are drawn from *a* and *b* through *O"*, the vanishing point.
7. Points *f* and *g* are located on lines *aO"* and *bO"* by using scale *EO"* (3 ft "back" from the zero point).
8. By erecting verticals from *f* and *g*, and lines through *O"* from other points on the front face, points *h*, *i*, *j*, *k* and *l* can be located. From these locations, the rest of the object can be drawn.



$a = 30$ degrees, $\theta = 60$ degrees, and $c = 96$ inches. Calculations have been made in inches with the results reduced to feet and inches.

To obtain scale distances and locations, Equations 1 and 2 are used. Thus

$$m = 96 \tan 60 = 13 \text{ ft } 10\tfrac{1}{4} \text{ in.}$$

$$n = 96 \tan 30 = 4 \text{ ft } 7\tfrac{1}{4} \text{ in.}$$

For convenience, so that numerically scales $C'D'$ and $C''D''$ will be one-half of scale CD, scale $C'D'$ is placed one-half of 13 ft 10¼ in., or 6 ft 5⅛ in. (m'), to the left of scale CD; and scale $C''D''$ is placed one-half of 4 ft 7½ in., or 2 ft 3¾ in. (n'), to the right of scale CD. Thus, Equations 3 and 4 need not be used in this example.

From Equation 5,

$$B = \frac{96\,b \cos 30}{96 + b \sin 30} = \frac{166.27\,b}{192 + b}$$

Values of b are substituted to produce the typical values of B shown in *Table* 1. Values of b are entered on scale OB, *Fig.* 1, at distances from O corresponding to B.

Similarly, from Equation 6,

$$B' = \frac{96\,b' \cos 30}{96 - b' \sin 30} = \frac{166.27\,b'}{192 - b'}$$

Substituting values of b' gives values of B' shown in *Table* 1. These values of B' are used to lay out scale $O'B'$, *Fig.* 1.

From Equations 7 and 8,

$$A = \frac{96\,a \cos 60}{96 + a \sin 60} = \frac{96\,a}{192 + 1.732\,a}$$

and

$$A' = \frac{96\,a' \cos 60}{96 - a' \sin 60} = \frac{96\,a'}{192 - 1.732\,a'}$$

By substitution of values of a and a', values of A and A' are obtained as shown in *Table* 2. These values of A and A' are used for scales OA and $O'A'$, respectively.

Rearranging Equation 9 and substituting the value c gives

$$D = 2c\sqrt{\frac{1}{2} - \frac{c}{2F}}$$

$$= 192\sqrt{\frac{1}{2} - (48/\sqrt{9216 + d^2})}$$

Again, substitution for d produces values of D shown in *Table* 3. Values so obtained are used on scale OD, and also in scale OC since the same amount of foreshortening occurs in both scales.

To produce a parallel-perspective chart, *Fig.* 6, the method just outlined to determine D, and the values given in *Table* 3, are used for scales OC, OD, $O''A''$ *and* $O''B''$. Values for scale EO'' are obtained by substituting in Equation 10. A value for h must be chosen, and for *Fig.* 6 has been set at 69 inches. Then

$$E = \frac{69\,e}{e + 69}$$

Values of E given in *Table* 4 are obtained by substituting values of e. These values are used for scale EO''. The zero point on scale EO'', *Fig.* 6, is placed h distance, or 5 ft 9 in., below HH since the zero point is at ground level and HH is at eye level.

Table 3—Values from Equation 9

d (ft, in.)	D (ft, in.)	d (ft, in.)	D (ft, in.)
0 0	0 0	4 0	3 8
6	5 3/16	6	4 0 1/16
1 0	11 1/16	5 0	4 4 3/16
6	1 5 3/16	6	8 1/16
2 0	11 7/16	6 0	5 0 3/16
6	2 4 1/16	6	4 1/16
3 0	10 7/16	7 0	7 3/16
6	3 3 1/16	6	10 3/16
		8 0	6 1 1/16

Table 4—Values from Equation 10

e (ft, in.)	E (ft, in.)	e (ft, in.)	E (ft, in.)
0 0	0 0	9 0	3 0 3/16
6	4 1/16	6	1 7/16
1 0	7 3/16	10 0	2 1/16
6	10 3/16	6	3 1/16
2 0	1 1 3/16	11 0	3 3/16
6	4 7/16	6	4 1/16
3 0	6 1/16	12 0	5 1/16
6	9	6	6 1/16
4 0	11	13 0	6 3/16
6	2 0 3/16	6	7 1/16
5 0	2 1/16	14 0	7 3/16
6	4 1/16	15 0	9
6 0	5 1/16	16 0	10
6	6 3/16	17 0	10 1/16
7 0	8 1/16	18 0	11 3/16
6	9 1/16	19 0	4 0 1/16
8 0	10 1/16	20 0	1 1/16
6	11 1/16		

How to Use the Charts: Practical use of the charts can perhaps best be shown with several specific examples. Method for making a drawing in angular perspective (with two vanishing points) is outlined in *Example* 1. *Example* 2 shows the method for a parallel-perspective drawing (one vanishing point).

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Gear Lubrication

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LUBRICATION can be a critical design factor with gears—particularly heavily loaded types. For all types of gearing, some sort of lubricating action is obviously necessary. For spur gearing, in which the teeth "roll" rather than "slide," lubrication problems are often assumed to be simple. The basic assumption is sometimes made that hydrodynamic bearing conditions exist —that a wedge-shaped film of oil supports the load.

But for gears which largely operate with relative sliding motion—worm, hypoid and similar gears—the problem is not so simple. Here, lubrication conditions are usually boundary, and nonfluid film lubrication largely dominates. The same statement can be made for starting conditions with "rolling" types of gearing before the fluid film is established, and often for high capacity gearing in which tooth-bearing conditions approach those of boundary lubrication.

The purpose of this series of articles is to outline and fill in major details of all types of gear lubrication—fluid and nonfluid. In the discussion, one major accent will be on oils and conventional types of lubricants. But equal weight will be given to nonfluid lubrication and additives. The reason is basic—these areas are largely the province of chemical physicists and, as such, are not nearly as familiar to designers as they should be.

Fundamental principles are reviewed in this article; the two remaining articles in the series will cover (1) the practice of gear lubrication and (2) design for gear lubrication, and suggestions for meeting unusual operating conditions.

Types of Relative Motion: Adequate lubrication is as important as proper design, workmanship and assembly with any piece of machinery where parts come into rubbing contact. To minimize wear and frictional losses, the moving parts have to be separated by lubricant films as far as possible. In order to appreciate the possibility of accomplishing this where the load is high and the motion is not a simple rotary one, such as with worm gears, the principal characteristics of lubrication and the kinds of relative motion between gears will be briefly discussed.

To appreciate lubrication requirements, a comparison can be drawn between the familiar spur gears and worm gears with respect to their relative motions. With spur gears the line of contact performs mainly a rolling motion, comparable to the movement of a roller in a roller bearing; sliding motion is subordinate. With hypoid and worm gears sliding motion predominates; hence the conditions of lubrication are more severe. Worm gears in particular, are more easily overloaded.

Types and Mechanics of Lubrication: Two kinds of lubrication are involved in gear lubrication (and generally in most lubrication): fluid or hydrodynamic lubrication, *Figs.* 1 and 2, and "thin film" or boundary lubrication, *Fig.* 3. Fluid lubrication is obtained when the film of lubricant is so thick that all rough spots protruding from the lubricated surfaces are well submerged under oil. In operation—that is, with relative motion of the parts—all friction takes place within the liquid lubricant film and appears as heat. This heat is partly conducted away by the oil and partly transferred to the metal surfaces, which in turn transfer it to the housing of the machinery and ultimately to the surrounding air. The faster the oil flow, the better the heat is removed.

The principal physical characteristic of the oil which determines whether fluid lubrication can

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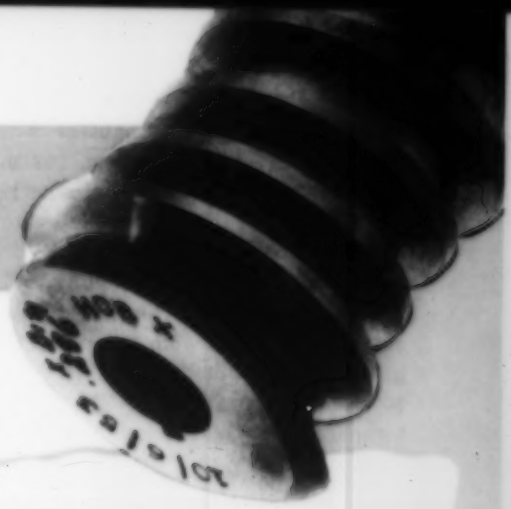


Part 1–Fundamentals and Problems

The theory and practice of gear lubrication has steadily grown more complex. As gear capacities increase and temperature limits expand, the role that the gear lubricant plays becomes highly important. The lubricant —its properties, characteristics and method of application— become as much a design factor as design of the gear itself. In this series of articles, the whole area of gear lubrication is summarized, with special emphasis on lubrication of higher capacity types of gearing, and on unusual operating conditions

exist is its viscosity. The higher the viscosity, the higher the load-carrying capacity, that is, the resistance of the oil to displacement or squeezing out.

But fluid friction (heat generated) also increases with viscosity of the oil. Since the lubricant is a liquid, given sufficient time and with sufficient pressure, lubricant of any viscosity will be squeezed out between mating surfaces until the asperities of the two surfaces approach so closely that boundary or imperfect lubrication begins, *Fig.* 3. This state has to be avoided as far as possible since it is always associated with wear. In fluid lubrication there is no wear whatsoever.

There are two ways of minimizing such displacement of the oil in the course of time under high pressure: (1) lowering the pressure, and (2) shortening the duration of its application. This explains why, for lower pressures and higher relative speeds of the mating surfaces (i.e., shorter duration of pressure), less viscous oils may be used or even required for the identical mechanism that would call for a highly viscous oil at high loads and low speeds.

No single oil can satisfy all operating conditions equally well, so long as fluid lubrication is the design objective. Of course, fluid lubrication is always the goal of intelligent design, lubrication and operation, even when it cannot be perfectly accomplished.

Oil Viscosity: Decrease of viscosity ("thinning") of lubricating oil with increasing temperature is a familiar phenomenon. When that decrease is small, the oil is said to possess a high "viscosity index." When the decrease is large, the viscosity index is low. In general, the former kind of oil is preferable to the latter.

In general, the ideal lubricating oil should have

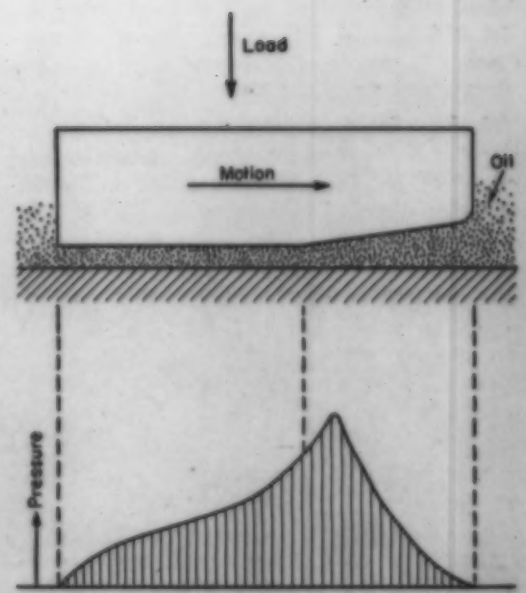


Fig. 1—Basic principle of fluid lubrication. Moving slipper forms a wedge-shaped oil film and floats on it. Pressure distribution in the oil film in a vertical direction is also shown

the same constant viscosity at all operating temperatures of the mechanism which is to be lubricated. If this were true, for instance, bearings could be calculated almost exactly. Since viscosity at the temperature at which the bearing has to operate enters like any other design factor into the calculation of the bearing, and since that bearing temperature never is exactly known, the designer ordinarily has to resort to an intelligent guess of the operating temperature. He then has to make allowance for the inevitable error and temperature fluctuations by applying a safety factor.

The lower the viscosity index of the oil, the larger the safety factor must be, because a small error in temperature corresponds to a large error in viscosity.

As a second example, consider the case of the so-called 10-20-30 engine oils. These are oils of unusually high viscosity index (synthetic oils or blends thereof), and the designation means essentially that the oil covers the viscosity range from SAE 10 to SAE 30. At low temperatures (for easier starting) it has the low viscosity of an SAE 10 oil and at the higher normal operating temperature of the engine it has about the same viscosity as an ordinary SAE 30 oil.

The preceding discussion of the decrease of viscosity with increasing temperature and the benefits of a high viscosity index, as well as the examples presented, refer primarily to cases where full fluid (thick film, hydrodynamic) lubrication dominates and thin film (boundary) lubrication occurs only during comparatively short periods of starting and stopping the engine.

Gear systems where sliding motion is predominant, such as worm gears, involve considerable permanent boundary lubrication, notably at low speeds; this condition decreases at higher speeds in favor of fluid lubrication. Thus, a reasonable decrease of oil viscosity with rising temperature may sometimes be beneficial. Reasons follow.

If two oils of the same crude but of different viscosity are considered, the more viscous oil is always the better boundary lubricant. Hence, it is preferable for lubrication of gears in the "sliding" category, notably in the starting or low-speed range, no matter how fast full speed is attained. As full speed is reached, the high viscosity desirable for starting may not be required because of decrease in the "squeezing out" time, as explained previously. A less viscous oil, so long as it stays on the teeth, has the advantage of faster heat dissipation and smaller viscous drag; thus, it will tend to increase efficiency of the mechanism. This state of affairs establishes itself automatically by the decrease in oil viscosity as the system warms up. Such considerations apply particularly to worm drives where the worm is underneath and normally immersed. They are included here in order to round off the discussion on viscosity index, to point out the complex interdependence of oil properties and operating conditions and the advisability of experimentation with specific designs.

As a general rule, higher efficiency and less wear are to be expected when worm and similar gears are operated with the more viscous oils.

Surface Finish and Wear: The previous conclusion is largely based on the part which boundary lubrication plays in gear operation. Boundary lubrication is always associated with wear.

Wear can be materially reduced by a high-grade surface finish, since under these conditions less

Fig. 2—Lubricating layer in fluid lubrication, schematically shown, with polar molecules

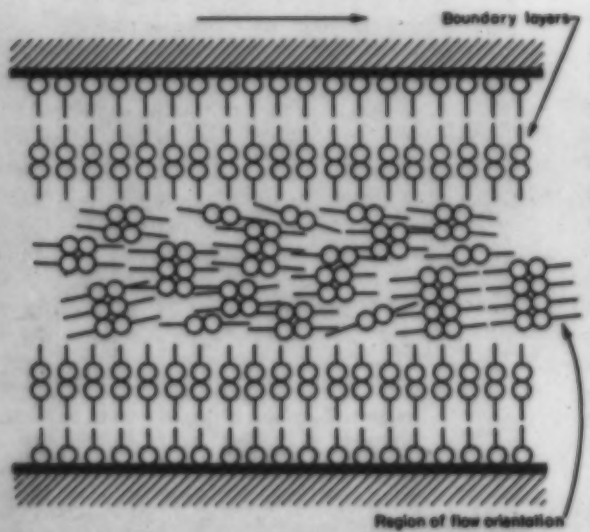
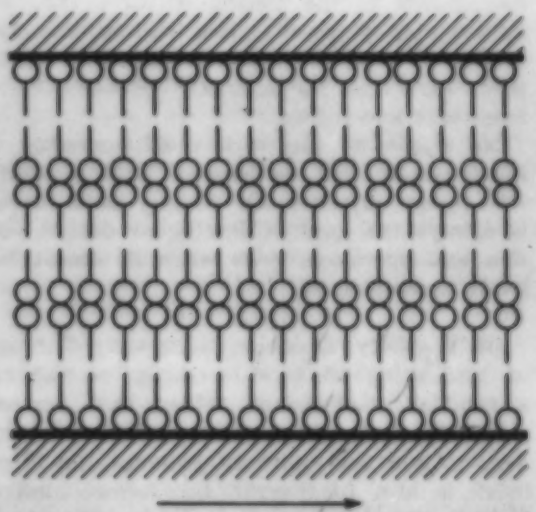


Fig. 3—Lubricating layer in boundary lubrication, with unimolecular boundary layer of polar molecules



interlocking of surface asperities takes place.

Expressed more precisely: as a rule, the smoother the surfaces, the thinner the oil film may become without transgressing the realm of fluid lubrication. This fact is the basic reason for the practice of running-in machinery.

All discussions involving fluid (hydrodynamic) lubrication are based, however, on the assumption that the oil firmly adheres to the metallic surfaces. Usually, that prerequisite seems to be adequately fulfilled.

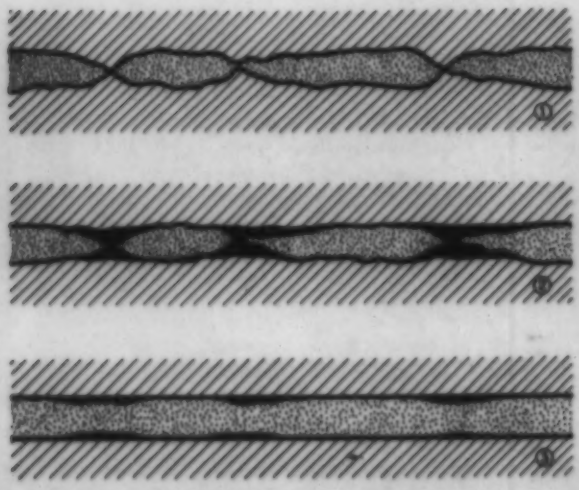
When there is reason to question "perfect" adhesion of the oil, new and not fully explored physicochemical factors have to be considered. Their significance can be appraised only by experiment, since—a fact well-known to the chemist—adhesion of the lubricant depends both on the metal and on the oil and, probably, also on the surrounding atmosphere.

Thus, the author has found that after prolonged running of a piston ring (cast iron, against steel with splash lubrication) the ring acquires a high polish but tends to repel oil without excessive wear, however. He tends to attribute this to the formation of an invisible oxide film. Another author, reporting high wear of cast-iron engine cylinders, attributed it to excessive smoothness of the surface and poor adhesion of the oil. Most experimenters, however, reach the conclusion that a very high-class surface finish is desirable. These contradictory opinions lend support to the hypothesis just expressed, that the result depends both on the metal and the oil. The surface oxide hypothesis seems to be supported by the practice of *porous* chrome plating where chromium plating is desired on cylinder liners.

Chromium and most aluminum alloys are always covered with an invisible oxide film to which, apparently, oil does not adhere as well as on most other metal surfaces, so that oil-retaining pores may be desirable.

As a general rule, however, a very high-grade surface finish is suggested with worm and similar gears, at least on the steel worm.

Fig. 4—Action of an EP additive. Black areas indicate chemical compound between the metal and the additive formed by local high temperatures at hot spots and gradually wearing off to leave a smoother surface



Extreme-Pressure and Similar Addition Agents: In practice, ideally smooth surfaces cannot be produced; if they could, they would not stay so for any length of time for a variety of reasons. Hence, one has to resort to other means for making unavoidable boundary lubrication as innocuous as possible; that is, to reduce or control the wear associated with it. This applies in particular to conditions where sliding coincides with heavy loads. The most familiar example is hypoid gears; worm gears belong basically in the same category. These are cases where, because of considerable sliding motion, boundary lubrication tends to prevail along with high pressures. These high pressures result in local high temperatures, (at the peaks of the "rough" surfaces), in local removal or chemical decomposition of the petroleum lubricant, metal-to-metal contact and "seizure," that is, welding and similar damage caused by irregular plucking out of metal particles.

To prevent damage, "extreme-pressure" additives are dissolved in the mineral oil. These—better called "extreme-temperature" additives—form chemical compounds with peaks of the surfaces at the high local temperatures. These compounds have much lower friction than metal against metal, they wear off only gradually, excessive local pressures are relieved, temperatures reduced and, as a result, a smoother surface consisting of a thin film of the compound is formed. *Fig.* 4 shows the action graphically.

Since EP additives function by chemical reaction, it follows that no single EP additive will be equally effective with all metal combinations. The usual commercial EP additives are adapted to use with steel against steel. Obviously, EP additives may also be used for running-in purposes.

Fatty acids and their metal salts (soaps) as well as their esters have been used as friction-reducing additives for many years ("germ process"). The acids and salts, too, react with metals but, in contrast to EP additives, at low operating temperatures, forming soaps with the substrate and firmly adhering to it. Resulting friction (in boundary lubrication) is low until the soap melts. At elevated temperatures they decompose leaving, probably, an oxidized surface. In contrast to EP additives, they are not effective as EP agents when added to oil in small concentrations.

Some lead soaps (e.g., lead-naphthenate) seem to occupy an intermediate position and are classified as "mild" EP additives. They are used mostly

in conjunction with powerful sulphur and chlorine-bearing EP additives. Their significant chemical action seems not to be established with certainty.

Summarizing, in order to avoid metal-to-metal contact and welding, the surfaces are contaminated by adding EP additives to the hydrocarbon oil which would otherwise act at high temperatures as a cleansing agent such as used in order to prepare metallic surfaces for soldering or welding.

As far as the resulting surface condition is concerned, good EP additives act like very fine polishing agents, for which reason they are often used as running-in agents.

Solid Lubricants: From the preceding dicussion of the action of EP additives it will be seen that ultimately solid lubricants are resorted to for the positive avoidance of metal to metal contact. Producing them on the spot as products of chemical reactions is just one method of doing it. Another method is to add the solid lubricant to the oil to form a very fine suspension. The results are not identical Both methods have their relative advantages and disadvantages, and the ideal procedure may lie in a combination of both.

In general, suspensions work satisfactorily when pressures are not too high. Experience shows that it is very important to use the solids in very small particle size ("colloidal"), presumably because they keep better in suspension and more particles are present per unit weight.

Solid additives are leaflet-shaped crystalline particles, comparable to decks of cards, which are easy to cleave between the "cards" and wettable by oil, *Fig.* 5. Graphite and molybdenum disulfide appear to be, so far, the best solid additives. The latter seems to have, moreover, EP lubricant properties because of its sulphur content. The soaps contained in greases seem to play a part as solid lubricants.

The most effective and rational means to minimize wear where it tends to assume dangerous proportions seems to be solid lubricants or solids-producing EP additives. They cannot be squeezed away nearly as easily as the liquid lubricant that serves as their carrier. EP additives produce solid lubricants by chemical action "on the spot," that is, preferentially on the roughness peaks of the solid surfaces, wearing them off on a molecular scale and thus smoothing the surfaces. Suspensions of graphite or molybdenum disulfide interpose solid flakes between the rubbing surfaces. These flakes tend to attach themselves more or less firmly to the surfaces, thus smoothing irregularities, which EP additives do by chemical action. Obviously peaks may be sometimes "missed" by solid particles in suspension, whereas they are the points of primary attack by EP additives. Addition of EP agents to suspensions may offer the best protection against excessive wear. Wear should not be confused with plastic deformation of the surfaces.

Additives to Preserve Lubricant Properties: A number of other additives, some of which are useful in gear oils, have one purpose in common.

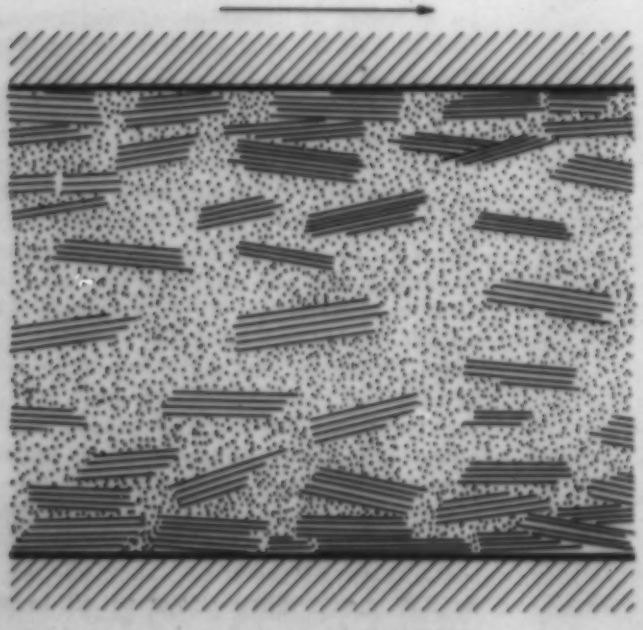


Fig. 5 — Lubricating layer with a solid lubricant (graphite leaflets). Dots indicate oil molecules, free and adsorbed to metal or graphite

namely, to preserve the original properties of the lubricant while in use. Such additives are (1) oxidation inhibitors, (2) detergents for holding solid oxidation products in suspension, and (3) antifoaming agents, since oil foam cannot maintain fluid lubrication. Other additives are (1) pour-point depressants, to prevent formation and precipitation of large paraffin wax clusters in certain oils at low temperatures, which would impair fluidity, (2) viscosity index improvers, and (3) amines to neutralize acids formed by oxidation.

Greases: Greases are suspensions of fibrous soaps in oil. The oil is selected according to fluidity requirements, and the soap mainly according to the operating temperature and any expected contamination by water. In general, greases are used where a mechanism cannot be adequately sealed against leakage of oil and entry of foreign matter.

Oils for Wide Temperature Ranges: Special and very difficult problems arise for the designer and manufacturer of machinery operating under high loads and sliding motion (where worm gears are used, for instance) intended to operate over such wide ranges of temperature as, for example, in some aircraft applications.

Special synthetic oils with very high viscosity index and adequate fluidity at the low temperatures, or greases containing these oils, are selected for such applications.

Satisfactory performance at low temperatures is obtained at the expense of fluid lubrication at ordinary and high temperatures, since viscosity of every fluid materially drops within such temperature ranges. Some lubricant specifications of the armed forces call for oils of the kind described. In the operation of such machinery as worm gears, boundary lubrication strongly predominates over fluid lubrication.

Running Properties of Metals and Alloys: Wherever boundary lubrication becomes significant, a group of properties of the metals and alloys becomes of importance in conjunction with lubrication. These properties are usually summarized as "running properties," a term which includes the running properties of different metal combinations, such as steel on bronze, etc. These properties ultimately determine, for a given oil, friction and wear. They include, first, physical properties—for instance, differential thermal expansion of different crystal grains of the metal, or of different constituents of an alloy, and precipitation from solid solution as with tin babbitt. Similarly, work hardening of the surface with many metals and alloys, and hardness in general, are included here. Second, running properties include chemical reactivity with the lubricant, as briefly mentioned in connection with EP additives. There may be more factors involved, somewhat depending on the definition of "running properties." The field is certainly not nearly fully explored.

Design and Lubrication: Lubrication is to a great extent maintenance. But sound lubrication principles must be borne in mind in design and manufacturing stages for gears.

The large and ever-increasing number of lubrication and lubricant testing machines shows how far we are from being able to make unqualified predictions with regard to many specific problems arising in practice. Thus, preceding discussions do not purport to be more than an attempt to summarize the basic factors that enter into the lubrication of gears.

The next article in this series will cover standard specifications for gear lubrication, use of extreme-pressure lubricants, solid additives, and synthetic lubricants.

ACKNOWLEDGMENT

The author wishes to express his appreciation for valuable discussions regarding this and subsequent articles with Messrs. Walter M. Schindler, director of research and development, Vard Inc., and Milton H. Sperling of Richfield Oil Corp. Illustrations, courtesy Vard Inc.

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Die Casting Standards

New design standards give practical recommendations for cored holes, flash removal, machining stock allowances, and ejector-pin marks

PRACTICAL production tolerances and practices for certain die casting design features are summarized in this article. Just issued by American Die Casting Institute, these standards supplement tolerance standards issued earlier this year (see "Tolerances for Die Castings," MACHINE DESIGN, May, 1955, Page 153).

Tolerances and recommendations represent normal production practice at the most economical level. Greater accuracy, involving extra work in production, can be specified, but additional cost may be involved.

Cored Holes: Maximum depths for cored holes, as related to diameters of the holes, are shown in *Table* 1. Where small-diameter holes are widely spaced, and cores are subject by design to full shrinkage stress, depths shown are not applicable.

Draft for Cored Holes: All cored holes must have minimum draft as shown in *Fig.* 1. For example, in a zinc die casting a cored cylindrical hole 2 inches deep will have a total draft of 0.042-inch for the 2 inches of depth.

Ejector-Pin Marks: Number and location of ejector pins vary with size and complexity of the die casting. Location shall be at the option of the die caster, subject to customer agreement where required. Ejector-pin marks may be raised or depressed 0.015-inch max. Normally, ejector-pin flash surrounding the mark will not be removed or, if this is not suitable, such flash may be crushed or flattened. Complete removal involves machining or hand scraping—extra operations at extra expense.

Flash Removal: Flash formed at the die parting line or where moving or separate die parts form the impression will be removed in accordance with *Table* 2. Complete removal involves additional operations. A tumbling operation is recommended as the most economical method of degating and flash removal where surface finish is not critical.

Machining Stock Allowance: A minimum of material should be removed for lowest cost and best metal properties. Choice of locating and checking surfaces should minimize process tolerance variations. For process reasons, interior surfaces and most detail in the die casting (involving use of moving die members) are formed by the ejector half of the die. Best results are attained if the die casting is located from ejector die surfaces for machining operations.

These considerations will usually result in a machining stock allowance of not less than 0.010-inch, to avoid excessive tool wear, nor more than 0.020-inch for all except very large die castings.

Other Standards: Copies of these and previously issued product standards can be obtained from American Die Casting Institute, 366 Madison Ave., New York 17.

Table 1—Maximum Depth of Cored Holes

Alloy	Maximum depth of hole (in.) for hole diameter (in.) of								
	1/8	5/32	3/16	1/4	5/8	1/2	5/8	3/4	1
Zinc*	5/8	7/8	5/8	1	1 1/2	2	3 1/2	4 1/2	6
Aluminum*	7/8	1/2	5/8	1	1 1/2	2	3 1/2	4 1/2	6
Magnesium*	7/8	1/2	5/8	1	1 1/2	2	3 1/2	4 1/2	6
Copper	..	..	..	1/2	1	1 1/2	2	3 1/2	5

*For holes larger than 1 inch in diameter, the diameter-depth ratio shall be 1:6.

Table 2—Flash Removal

Description	Heavy Gates and Overflow	Light Gates and Overflow	Parting Line and Seam Flash	Flash in Cored Holes	Sharp Corners
Degated	Rough within 1/8-in.		Excess only broken off	——Not removed——	
Commercially trimmed*	Flush within 1/32-in.		Flush within 0.015-in.	Removed within 0.010-in.	Not removed

*"Commercially trimmed" does not include washing to remove unattached material.

Fig. 1—Draft requirements for cored holes in die castings. Total draft on both sides of hole is shown

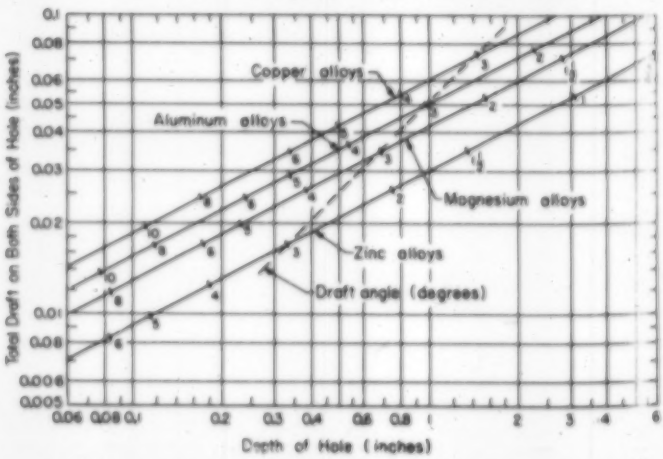

Fig. 1—Below—Section of an antifriction bearing retained with a snap ring (National Aircraft Standards 50 and 51)

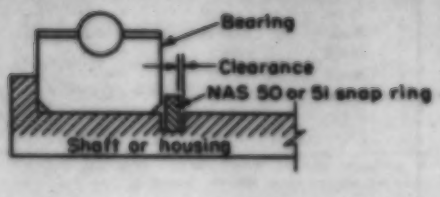

Fig. 2—Right — Tool used for roller staking causes a flow of metal from assembly housing over outer race chamfer of bearing to be retained

Simple mass-assembly methods for BEARING RETENTION

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BEARING retention becomes increasingly more difficult with new designs. Prime objective is often to use methods that do not add weight or complicate design and manufacture. The bearing retention method must be selected on its individual merits. Selection tends to be influenced by weight saving, ease of installation and cost.

This article presents advantages and limitations of certain bearing retention methods used by Boeing Airplane Co. to retain antifriction bearings. These methods can be classified into five basic types:

1. Bolted assemblies, which include bolts, nuts, locknuts, shoulders, cover plates and similar counterparts.

Fig. 3—Details of filleted depressions produced during roller staking. Type *A* configuration is for self-aligning bearings. Type *B* is for all other antifriction bearings

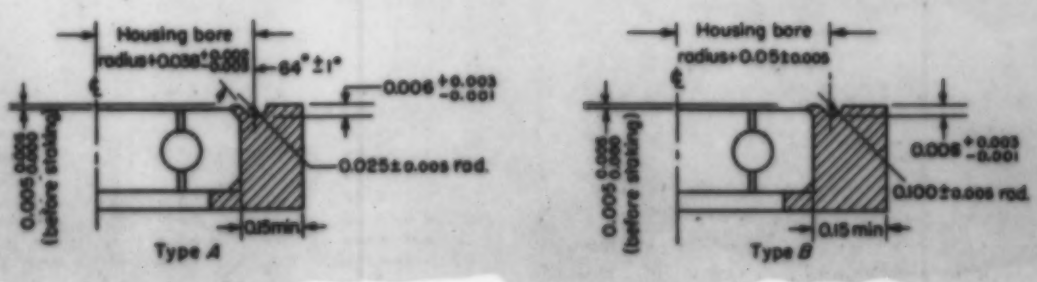


Table 1—Comparative Ratings of Bearing Retention Methods

Retention Method	Reliability: Thrust Loads*	Reliability: Differential Movement†	Ease of Installation	Simplicity of Design	Weight Saving	Ease of Inspection	Bearing Service Removal and Replacement	Adaptability to Housing Material	Cost Saving
Bolted assemblies	Good	Good	Fair	Poor	Poor	Good	Good	Good	Poor
Snap rings	Fair	Poor	Good	Fair	Poor	Fair	Good	Good	Poor
Roller staking	Fair	Fair	Good	Good	Good	Good	Fair	Fair	Good
Ball-point staking	Fair	Fair	Good	Good	Good	Good	Fair	Fair	Good
Point staking	Fair	Fair	Fair	Good	Good	Good	Fair	Fair	Good
Ring swaging	Good	Good	Poor	Fair	Poor	Fair	Poor	Good	Poor
Cementing	Fair	Good	Poor	Fair	Good	Poor	Poor	Good	Fair

*Bolted-assembly and ring-swaging methods are rated with respect to primary thrust loads, while the remaining methods are rated with respect to secondary thrust loads. †End play of bearing outer race within housing.

2. Snap rings.
3. Staking, which includes roller staking, ball-point staking and point staking.
4. Ring swaging.
5. Bonding.

Relative merit of each method can best be illustrated by comparative ratings of each one with the fundamental requirements for bearing retention, *Table* 1. Thrust loads considered are primary and secondary. For purposes of this discussion, primary thrust loads are those loads to which parts have to be designed to insure safe operation of an airplane and all its major component parts; all other loads are considered secondary.

BOLTED ASSEMBLIES

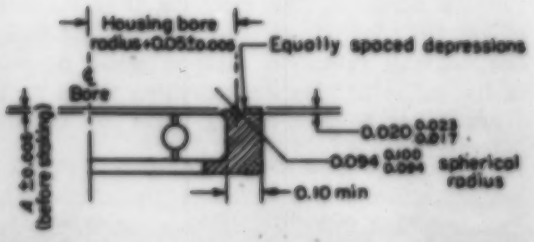
This method encompasses numerous ways to retain bearings, and can only be generalized as to design detail. Some of the more common ways are machined shoulders, nuts and bolts, bolted cover plates, spacers and split housings. Although this method is the most reliable in resisting primary thrust loads, it generally increases number of component parts, design detail and manufacturing time. As a result, cost and weight of assemblies are increased.

SNAP RINGS

This bearing retention method is limited to designs involving secondary thrust loads, even though the rings themselves have rather high shear strengths. This is due to the end play or clearance which exists in assemblies using snap rings, *Fig.* 1. The existence of clearance or end

Fig. 4—Tool used for ball-point staking. The 3/16-inch balls produce depressions circumferentially around bore of bearing housing

Fig. 5—Design details for bearings retained by ball-point staking



Bearing OD (inches)	Dimension A (inches)	Number of Depressions
Up to 0.750	0.020	5
0.751-1.000	0.020	6
1.001-1.250	0.020	4 or 8
1.251-1.625	0.020	5 or 10
1.626-2.000	0.040	6 or 12
2.001-2.250	0.040	7 or 14
2.251-2.500	0.040	8 or 16
2.501-2.875	0.040	6, 12 or 18
2.876-3.250	0.040	5, 10, 15 or 20
3.251-3.750	0.040	6, 12, 18 or 24
3.751-4.500	0.040	7, 14, 21 or 28
4.501-5.000	0.040	8, 16, 24 or 32
5.001-5.750	0.040	6, 12, 18, 24, 30 or 36

play is inevitable, in that the groove must be wider than the snap ring width to permit assembly. Clearance or end play is accentuated by the accumulation of snap ring, bearing and groove tolerances.

Designs that permit the use of this method may have to allow complete inspection of the following items to insure reliability of the installation:

1. Shaft or housing diameter
2. Groove diameter
3. Groove width
4. Distance of groove from shaft end or housing surface
5. Installed snap ring dimensions

At Boeing, snap rings removed from an assembly are prohibited for reuse on that or any other assembly. This decreases the possibility of using rings that have been permanently deformed during installation or removal.

STAKING

Staking is accomplished by a manufacturing process which causes a flow of metal from the assembly housing over the outer race chamfer of the bearing to be retained. The various configurations produced are numerous. Those outlined here are produced by roller, ball-point, and point staking. Ball-point staking and point staking induce stress raisers; therefore, additional housing thickness is required on critically stressed parts.

Roller Staking: The tool used for this bearing retention method is shown in *Fig.* 2. The filleted and circular depression is produced by rotating the staking tool in a drill press, at approximately 150 fpm while the rollers or wheels are in contact with the housing surface.

Two configurations of depressions are used and are produced by use of different rollers. Details of these filleted depressions are shown in *Fig.* 3. An assembly may be roller staked on both sides provided the housing thickness equals the maximum bearing width within +0.005, −0.000. Type *A* configuration is used for staking self-aligning bearings, and Type *B* is for staking all other antifriction bearings.

Roller staking is applicable for use with wrought or cast aluminum, magnesium and steel alloys, provided the steels are not heat treated to strengths above 145,000 psi.

As a bearing is replaced, the subsequent roller staking results in less metal flow over the outer bearing race chamfer, thereby reducing its thrust carrying capacity. As a rule of thumb, the allowable thrust capacity, in pounds, is 333 times the bearing OD in inches for aluminum and steel, and 165 times the bearing OD for magnesium. These capacities are based on second bearing replacement.

Ball-Point Staking: The type of tool used for this method is shown in *Fig.* 4. The 3/16-inch steel balls project above the face of the tool sufficiently to cause circular depressions to be formed in the housing when the tool is brought into contact with the housing surface and static pressure is applied. The tools are designed to produce these

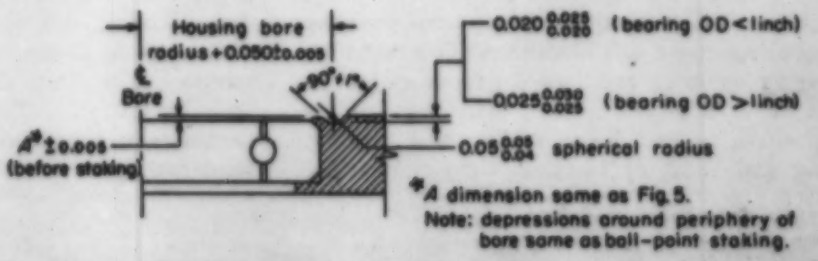

Housing bore radius +0.050 to 0.005
Bore
90° ± 1°
A* ±0.005 (before staking)
0.020 +0.025 −0.030 (bearing OD < 1 inch)
0.025 +0.030 −0.035 (bearing OD > 1 inch)
0.05 +0.05 −0.04 spherical radius
*A dimension same as Fig. 5.
Note: depressions around periphery of bore same as ball-point staking.

Fig. 6 — Details for bearings retained by point staking

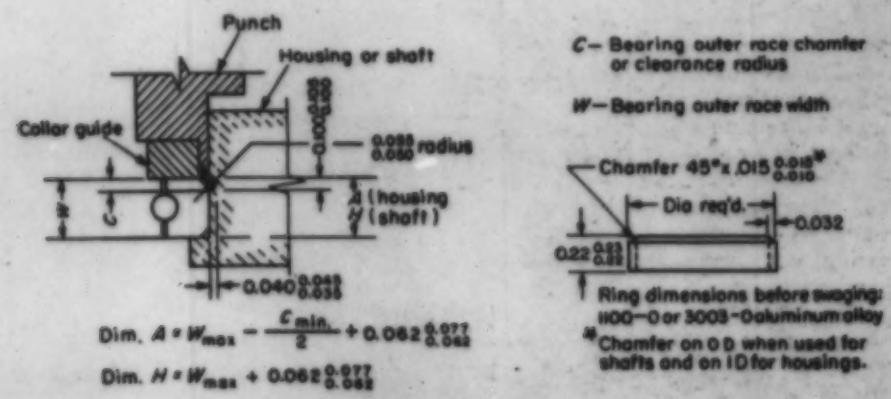

Punch
Housing or shaft
Collar guide
+0.005 −0.000 radius
A (housing)
H (shaft)
0.040 +0.045 −0.035
Dim. A = W max − C min./2 + 0.062 +0.077 −0.062
Dim. H = W max + 0.062 +0.077 −0.062
C — Bearing outer race chamfer or clearance radius
W — Bearing outer race width
Chamfer 45° x .015 +0.015* −0.010
Dia req'd.
0.032
0.22 +0.03 −0.02
Ring dimensions before swaging: 1100—O or 3003—O aluminum alloy
*Chamfer on O D when used for shafts and on I D for housings.

Fig. 7—Design for retention of bearings by ring swaging

depressions circumferentially around the bore of the housing. Space interval for these depressions can be infinitely varied; however, approximately ½-inch intervals are preferred. Thrust-carrying capacity is considered to be 53 lb per depression. The design detail for this method is shown in *Fig.* 5.

If it is desirable to stake both sides of the assembly, a shim must be used to maintain the required *A* dimension opposite the side initially staked. Ball-point staking permits an assembly to be restaked, provided new depressions can be produced without superimposing on existing ones.

Use of ball-point staking is limited to wrought aluminum and steel alloys, provided the steel is not heat treated to strengths greater than 145,000 psi. Cast alloys do not have sufficient ductility to prevent occurrence of radial cracks within the depressions.

Point Staking: The type of tool used for this method is the same as shown in *Fig.* 4, except the steel balls are replaced with spherical-end carbide projections. Point staking was developed to provide a simple method for retaining bearings in assemblies made of steels heat treated within the strength range of 145,000 to 200,000 psi. Previous experience in the attempt to ball-point stake alloy steels in this higher strength range resulted in excessive fracture of the steel balls. Details for bearings retained by point staking are shown in *Fig.* 6.

RING SWAGING

This method of retaining bearings is used for carrying thrust loads in more or less permanent installations. Ring swaging is accomplished by pressing or forcing a soft aluminum-alloy ring over the bearing chamfer and into a groove either on a shaft or in a housing bore. This method assures positive contact between ring and bearing, and ring and shaft or housing, thus eliminating end play. Three inherent disadvantages to this type of retention method are:

1. Difficult to remove.
2. New ring required for each replacement.
3. Danger of cracking the housing when forcing the ring into the groove.

The standard design for ring swaging was determined empirically and found to be optimum for design and fabrication, *Fig.* 7. The swaging ring is made from flat stock as shown. Ring swaging is not limited to any particular material or condition.

CEMENTING

Bearings are bonded or cemented into housing by an epoxy cold or thermosetting resin (Epon VI, Shell Chemical Corp.). Bearing assemblies utilizing this process are usually cured at room temperature for six days, rather than at 165 F for two hours (as usually recommended), due to the detrimental effect of elevated temperature on the bearing. The bonded joint is good in shear and fatigue, provided careful quality control is exercised during manufacture and installation. Surfaces to be bonded should be chemically clean, and pot life of the resin should not be exceeded. This method of retention is applicable to all wrought or cast aluminum, steel and magnesium alloys. The use of cementing has been somewhat limited due to the following disadvantages:

1. Extremely difficult to remove bearings for replacement.
2. Cannot be used to retain bearings with external oil ring grooves.
3. Rigid manufacturing control does not lend it to good production.
4. Does not lend itself to ease of inspection control.

There are two types of housing bore configurations used, *Fig.* 8. Type *A* is preferred; however, Type *B* must be used if the design requires the bearing to be aligned and concentric within the assembly. The limit design shear strength of the joint is 450 psi. The full bearing width is used to compute the joint strength for Type *A*, and combined groove widths for Type *B*.

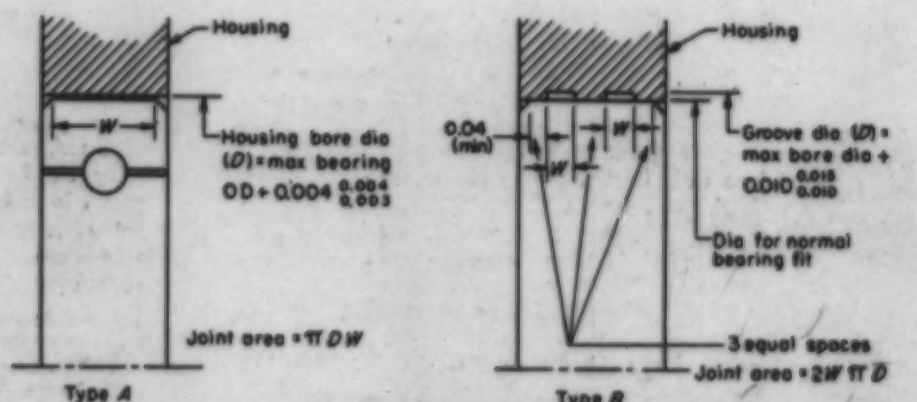


Fig. 8 — Details of housing bore configuration used in retaining bearings by cementing. Type *A* is preferred. Type *B* is for designs requiring the bearing to be aligned and concentric within the assembly

When to Specify

SPECIAL MOTORS

Factors in deciding whether a modified standard or custom-designed motor are practical and economical for a particular product design

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ONE OF THE principal reasons for using special motors is design latitude. Basically, any designer is faced with two choices in specifying a motor. He may design his product to fit one of the readily available standard or definite-purpose motors, or he may specify a motor with special electrical or mechanical characteristics to fit the product design.

Obviously, a standard motor is less expensive—as far as the motor is concerned. But a special motor may give the product highly desirable sales or service features. And it may even lower total manufacturing cost if it can be better integrated into the product design.

The most logical course of action if a special

Fig. 1 — Evolution of a special motor: *A*—standard 1/3-hp, 1725 rpm, split-phase motor with rigid base; *B*—end bells changed for face mounting and leads brought out shaft-extension end to make totally enclosed oil burner motor; *C*—special front end bell, removal of rear end bell, and special shaft extension fit motor for waste disposer application; *D*—change of front and rear end bells, and motor adaptation for vertical mount, permit use on floor polishers; *E*—face-mounting end bell with through-bolts, special shaft extension, and addition of capacitor, adapt motor for lawn mowers

motor is desired is to make the fewest and least expensive changes from standard motor features, *Fig.* 1. This article provides a guide to (1) the necessary steps in deciding whether a motor should ultimately be standard or special, and (2) the economics of motor modifications, so motor costs may be estimated at an early stage in the design.

Four Basic Questions: A designer will go a long way toward getting the best motor for his product if he asks himself four questions and then answers them as fully as possible:

1. What must the motor do?
2. Can standard motor be used?
3. What modifications are needed?
4. Are the modifications economical?

The following sections will cover the major factor to be considered in answering each question.

What Must the Motor Do?

Usually, in an evaluation of motor needs, the principal concern is the amount of rotational torque needed to move the load. This, of course, is a prime consideration. But many other, equally important factors should be precisely evaluated before a motor is selected or specified. Among these are: power supply, load characteristics, duty cycle, ambient temperatures, environment, mounting and safety.

Power Supply: Definition of the power supply is important, obviously, from the standpoint of product use. For example, motors designed for 25 or 50-cycle power will generally be heavier, larger and costlier than those for 60 cycles.

In the United States, this fact is less important so far as ac power supplies are concerned because 60-cycle power is common. Predominating supplies are: 115 and 230 volts 60-cycle single-

What Are Special Motors?

FUNDAMENTALLY, a motor is "special" if its electrical and/or mechanical requirements fall outside either Standard or Definite-Purpose motor outlines. One other factor, however, must be considered. That element is production volume. A good example is the motor designed for a particular waste disposer. This motor is, even today, electrically and mechanically special. But it is leaving the realm of special motors.

During the first year of waste disposers, the market was about 5000 units. Very few motor manufacturers were interested in taking on the development of a motor to fit the disposer. Only about 20 per cent of all motor manufacturers were interested in the production contract.

In every sense of the word, the motor was special. As a hypothetical example, the designer of the waste disposer could get his motor for, say, $20 per unit.

Within a few years the market for the disposer grew to between 50,000 and 100,000 units per year. This production volume is attractive to about 80 per cent of the motor manufacturers. Such volume warrants die castings, special tools and automatic winders. Economies of larger runs bring the price down to $18 per unit.

The motor, however, is still classed as special.

As the market gets even larger, virtually all manufacturers are interested. Only a few, though, will be willing to install automatic equipment to produce the motors *en masse* and at prices of about $16 per unit or even lower. About 80 per cent of the manufacturers will lose interest and seek projects which better fit their present manufacturing techniques.

But the other 20 per cent—those manufacturers willing to put the motor on a mass-production basis—will, as a result, take the motor out of the special class and put it into the class of motors known as "definite purpose." Similar motors in this class are furnace-blower, refrigerator, jet-pump and washing-machine motors.

Thus, a motor's designation depends on three factors: electrical design, mechanical design, and production volume.

Meat Slicer

Mechanical Requirements: Motor drives a rotating blade through worm-gear reduction. High starting torque load causes axial thrust on motor from worm gear. Motor must operate at extremely low noise level. Motor must be totally enclosed. End bell on shaft-extension side must have machined rabbet to fit gear box. Special shaft extension to receive worm. Outside contour of motor smooth and free of irregularities and sharp corners so machine can be wiped clean. No grease or oil leakage permitted from the machine. Outside of the motor primed with zinc chromate so entire machine can be painted white. Leads brought out through end bell and gear box so no leads will appear outside motor.

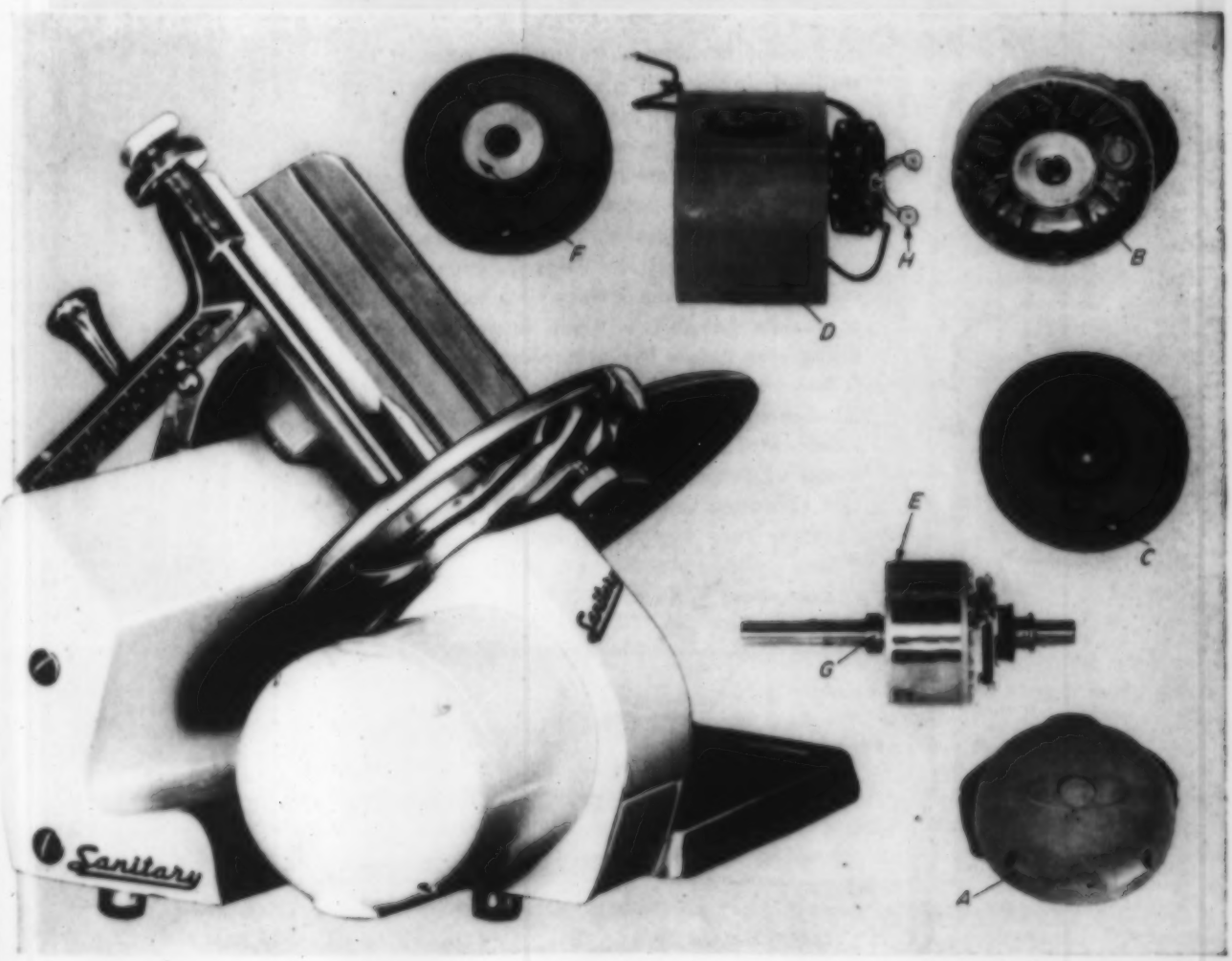
Motor Design: Two new end bells designed. Exposed end bell made smooth and streamlined; bearing well put inside motor so it does not protrude *(A)*. Generous sections and much ribbing inside both end bells increase rigidity and prevent vibration, thus reducing noise *(B)*. Drilled hole and grommet on gear-box end provide lead exit hole *(C)*.

Generous magnetic sections reduce magnetic saturation — a prime excitation force for noise *(D)*. All concentricities and roundness of machined parts held to very close limits to assure an even air-gap *(E)*, reducing so-called "slip" noise which is low-frequency modulation of the basic noise. Bearings made of a special material; normal clearance between bearing and journal reduced to prevent noise caused by loose bearing fits *(F)*. Sintered thrust collar running against hardened steel washer absorbs axial thrust *(G)*.

Coast time of machine is quite long. To prevent noise caused by centrifugal-switch spool rubbing on starting switch during deceleration after switch closes, felt pads are added to centrifugal switch *(H)* contact arms.

Motor Data: Split-phase, ¼-hp, 1725 rpm, 55 C continuous temperature rise, totally enclosed. Power supply: 115 v ac, 60 cycle, single phase.

Company: Sanitary Scale Co.



Submersible Deep-Well Pump

Electrical Requirements: **Under normal operating conditions, pump and motor deliver water from varying depths against varying pressure heads. Motor must continue to drive pump even if line voltage drops to 95 volts. Motor must supply enough starting torque to break away and accelerate pump after unit has been idle; unit may have to operate against sand or silt settlement and algae growth in pump parts.**

Mechanical Requirements: **Entire motor and pump unit fits into 4-inch well casing and operates submerged. Shaft extends through rotating seal and couples directly to pump shaft; it must be made of corrosion-resistant material. All exposed elements watertight; all motor parts run submerged in oil and must be made of materials that can operate in oil without contaminating oil.**

Motor Design: **Electrically, a capacitor-start induction motor is suitable. Cable sizes, insulations, wiring and spacing in the control box, etc., conform with National Electric Code.**

Stator fits closely in brass tube with concentricity maintained so end bells supported from this tube allow rotor to turn freely. In this regard, air gap between stator and rotor is also important. To meet these conditions, punching is made approximately 3.5 inches in diameter. Laminations welded together at 5 places for rigidity. Outside diameter ground to a close tolerance so stator can be pressed into tubing *(A)*. Slot insulation inert to oil used, and wound stator varnished by vacuum impregnation and baked *(B)*. Leads made of oil-resistant plastic insulation *(C)*.

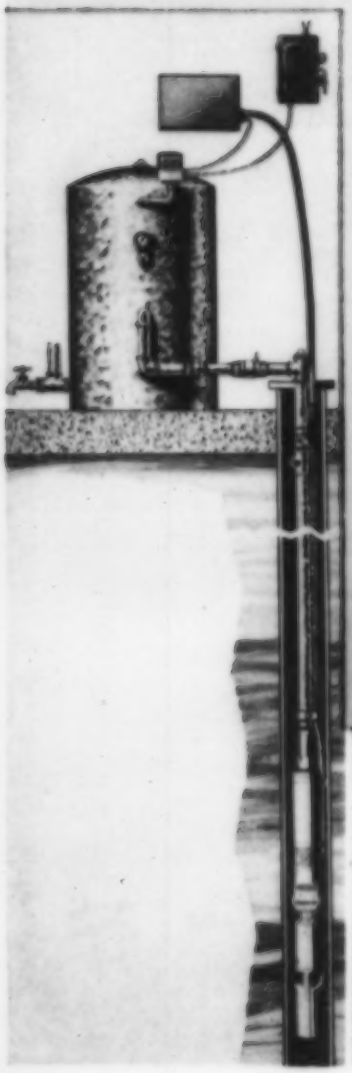
Special stator windings designed to meet torque requirements. Special relay, capacitor and overload device (to protect against rotor stalling) operate at ground level. Stator leads are brought out of the stator through the pump housing and connected to cable in well.

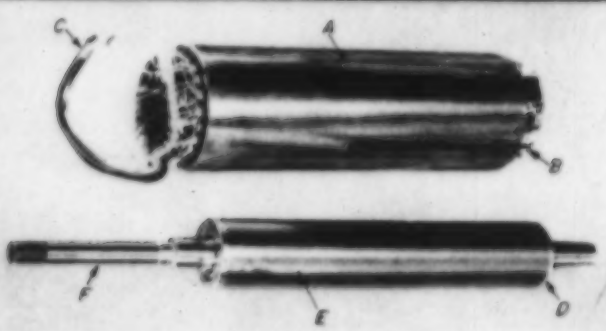
Speed is of prime importance, and speed increases as rotor resistance goes down. For lowest rotor resistance, rotor conductors made of copper bars and end rings. To provide maximum conducting area, rotor slots extend inward as far as possible without magnetically saturating iron below the rotor slots *(D)*.

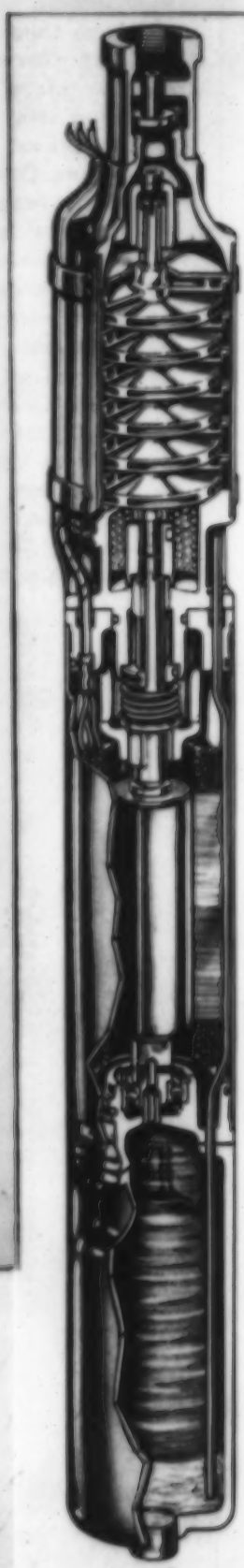
Rotor shrunk onto shaft to insure a tight fit *(E)*. Entire unit ground, after assembly, to provide necessary size and concentricity. Shaft made of Type 416 stainless steel, with extension threaded to couple directly to pump *(F)*.

Motor Data: **Capacitor-start, ½-hp, 3450 rpm. Power supply: 115 v ac, 60 cycle, single phase.**

Company: **F. E. Myers & Bro. Co.**







phase; 220/440 volts 60-cycle 3-phase; and 208 volts 60-cycle 3-phase. Direct current is available in some large metropolitan areas. Of course, rectified ac is often provided in industrial machines to power adjustable-speed dc motors. In some machines, particularly automobiles, only low-voltage dc is available.

If foreign markets are considered, clear specifications of ac power supplies are quite important. In this case, the designer should acquaint himself with the power available in foreign locations, *Table* 1. The table gives only the predominating voltage in a country. If two voltages are listed, an asterisk precedes the predominating system.

General Load Characteristics: Three factors relative to the driven load are most important to the initial evaluation of a motor's requirements. These are: product speed, torque, and inertia.

A machine's operating *speed* must be known to calculate the horsepower rating of the driving motor. In addition, any decision on coupling method is determined by speed of operation.

Generally speaking, most appliances and devices run at lower speeds than the motors. Hence, some form of speed reduction must be considered. In small-power devices, belt drives are the most common and least expensive. Worm and spur-gear reducers are also popular because these units are available as integral parts of motor packages. Worm-gear reducers are desirable from a space standpoint because high ratios can be built into small spaces. Spur-gear reducers are more efficient, but require more space.

Certain types of motors are limited in speeds at which they can be run—particularly induction motors. Where such motors appear suitable, it may be wise to modify the basic product design to permit direct coupling. But a word of caution. While direct coupling is desirable, direct coupling should not be used at the risk of specifying a motor with an abnormally low speed range. Motor cost and weight increase as motor speed or frequency are reduced. *Table* 2 lists the most common speeds for small induction motors. The least expensive and most popular of these is the 1800 rpm 60-cycle motor. Induction motors in speeds below 850 rpm are not practical in fractional or small integral-horsepower sizes.

As with speed, product *torque* must be known to set a horsepower rating.

A definite knowledge of peak torques is particularly important. The reason: a considerable safety factor is built into a motor to overcome peak torques. If these torques are precisely known, excessive safety factors can be eliminated, and a smaller, lighter and perhaps better-performing motor may be obtained than if only estimated torque data are known.

In some cases, it may be impractical or even impossible to determine torque values before the machine is built. In these cases, it is not uncommon for a motor supplier to furnish a standard motor merely to determine torque requirements of the load.

The ideal condition regarding torque is to have no peaks—a condition found in such devices as a centrifugal pump moving a liquid of constant viscosity. This condition usually leads to the lightest and least expensive motor.

Product *inertia* can be a motor designer's nightmare, emphasizing the need for its careful evaluation in initial development stages.

Background here is this: By definition, inertia is the property of a body at rest to remain at rest, or in motion to remain in motion. The motor must act against both. And the motor must supply energy until inertia is overcome. Because en-

Table 1—World Power Supplies

Country	—De Voltage— Preferred	Other	—Ac Voltage— Preferred	Other	—Frequency— Preferred	Other
Canada	110	...	110*	115, 150	60	25
Mexico	110	220	110, 125	115, 220, 230	60	50
Argentina	220*	...	220*	225	50	60, 43
Brazil	...	...	127	120, 220	50	60
Chile	220	110	220*	.....	50	60
Uruguay	220	...	220*	.....	50	..
Venezuela	110	220	110*	220	60	50
Belgium	220	110, 120	220*	127, 110	50	40
France	110	220, 120	110*, 115*	120, 125, 220, 230	50	25
Germany	220	110, 120, 250	220*	127, 120, 110	50	25
Italy	120	220, 150	150*, 127*	125, 115, 220, 110	50 ..	.. ..
Netherlands	220	...	220	120, 127	50	..
Portugal	220	150	220*	125, 110	50	42
Spain	110*	120, 115, 105	120*	125, 150, 220, 130	50	..
Sweden	220	110, 120	220* 110*	190, 127, 125	50	25
China	220	110	110*, 200*	220	50	60, 25
India	220	110, 225	230	220, 110	50	25
Japan	100	...	100*	110	50	60
Australia	220*, 240*	200, 230	230*, 240*	200	50	..

*Predominating system. Reference: U. S. Department of Commerce. Industrial Series No. 83.

Table 2—Standard Induction-Motor Speeds*

Synchronous Speed (rpm)	Approximate full-load speed (rpm) for . . . Shaded-Pole Motors	Permanent Split-Capacitor Motors	All Other Motors
60-cycle Current			
3600	....	3250	3450
1800	1550	1625	1725
1200	1050	1075	1140
900	800	825	850
50-cycle Current			
3000	....	2700	2850
1500	1300	1350	1425
1000	875	900	950

*For fractional-hp sizes. From NEMA Standards.

ergy is the product of power and time, and because a motor may be delivering its maximum power at any speed to the load, the amount of inertia will determine acceleration time. If this period of acceleration is too long, thermal failure of the motor will result.

Another important point: If a motor must reverse the load from full speed in one direction to full speed in the opposite direction, inertia is the limiting factor. Reversal is generally twice as tough on the motor as simple acceleration.

Here are two examples of inertia influence:

With devices such as furnace blowers and cream separators, the motor must not accelerate the load too rapidly because of adverse effects on other parts of the system. In these devices, motors with low starting and accelerating torques are required. However, special motor components may have to be included to guard against failure which may result from longer acceleration time.

An opposite illustration is a special appliance in which the motor drives a wheel of considerable

Food Waste Disposer

Mechanical Requirements: **Motor supplied minus end bell on shaft-extension side *(A)*. Frame machined to mount directly on cutter-housing casting in disposer. Entire unit held together with through bolts. Motor shaft *(B)* extends through sleeve bearing and water seal assembly mounted on unit. Disposer cutter mounts directly on ground taper on shaft and is held by nut on threaded portion of shaft. Entire unit, motor and outer assembly, enclosed with sheet metal to give smooth external appearance. Sleeve bearings used on motor. Motor operates vertical shaft up with thrust load taken by top bearing.**

Electrical Requirements: **Running torque of motor is in standard 1/3-hp range. However, torque must prevent rotor stalling when grinding chamber is loaded. Starting torque may have to be higher than normal to free a jammed unit. Special winding *(C)* meets these conditions. While motor is totally enclosed by sheet metal, cooling is possible; space within housing permits circulation of air, and cold water flows on top casting. Must be approved by Underwriters' Laboratories; motor must meet specifications in *Standard for Industrial Control*. Entire assembly must meet *Standard for Motor-Operated Appliances* and pass specific tests for garbage disposers.**

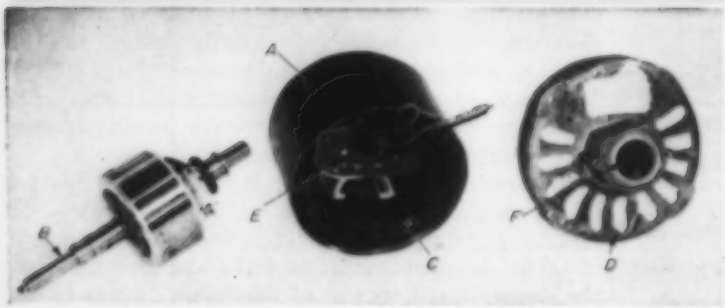
Motor Design: **End bell has specified rabbet diameter, bearing size and location, end turn clearances, through-bolt circle, and length and thread on through bolts. End bell provides: maximum air openings for ventilation, a well *(D)* to mount a starting capacitor since totally enclosing sheet metal prevents normal outside frame mounting, a hub at the lower end to mount sheet-metal enclosure, and a mounting for special thermal overload device *(E)*.**

Die casting for the end bell provides the hub by inverting normal bearing construction — bearing well is located outside casting rather than inside *(F)*.

Other features include: special winding to meet torque conditions, and electrical components designed for limited-ventilation conditions.

Motor Data: **Capacitor start, 1/3-hp, 1725 rpm. Power supply: 115 v ac, 60 cycle, single phase.**

Company: **National Rubber Machinery Co.**



inertia through a belt reduction. The motor is mounted on a hinged plate attached to a spring to provide proper belt tension. This system was, in the original concept, intended to bring the wheel up to speed as rapidly as possible. However, when this condition was met, the initial starting shock caused belt slippage and excessive belt wear. Finally, it was decided to lower the starting torque and acceleration of the motor, sacrificing some of the acceleration time but preventing belt slippage and minimizing wear.

Duty Cycle: Many devices are required to operate continuously, 24 hours a day for many years. On the other hand, on some devices, a motor runs for several hours and then is off for several hours. In either case, if the motor attains its ultimate temperature on any one cycle of operation, it is considered to be a continuous-rated motor. There are, too, a large number of devices that require intermittent duty of such short duration that the motor never attains the ultimate temperature.

For both fractional and integral-horsepower motors, a clear definition of duty cycle is important. Severe cycles can easily lead to thermal failure of an inadequate motor. On the other hand, a designer should not be too prone to select a continuous-rated motor just to be on the "safe side." While most motors, with the exception of series-wound units, are rated for continuous-duty service, there may be excellent opportunities to be "safe" and still save very valuable space and weight by using a smaller motor rated for intermittent service. Only a close evaluation of duty cycle will reveal this opportunity.

In defining duty cycles, the designer should bear in mind that off time between any two cycles should be sufficient to allow the motor to cool to within 5 F of room ambient temperature.

Ambient Temperature and Motor Enclosure: Ambient conditions of the machine should be defined. Four important motor features hinge on this definition: (1) amount of active material (windings, iron, etc.) in the motor, (2) type of insulation used, (3) cooling method, and (4) type of lubricant used.

A standard motor is designed for 40 C maximum temperature rise above ambient and should operate satisfactorily in ambients not exceeding 40 C. *Table* 3 lists standard temperature rises for motors having continuous-duty ratings. Short-time rating temperature rises for small-power motors are listed in *Table* 4.

These temperature rises are based upon measurement by thermometer method. If the resistance method, or a thermocouple on the winding, is used to determine temperature, the temperature will be 10 C higher than that shown.

In addition to this full-load temperature rise, a standard general-purpose 40 C motor will normally carry a service factor rating, *Table* 5. This service factor is a multiplier which, applied to the normal horsepower rating, indicates a permissible loading which may be carried under the conditions specified for the service factor. In general, this service factor shows how much a motor may be loaded beyond full load without attaining a dangerous temperature in the winding insulation.

As far as insulation is concerned, there is also a safety factor. However, insulation does not have an exact temperature at which it will fail. Long time tests show that insulation life is a function of operating temperature, and the limits are selected to give long, trouble-free service.

Offhand, this data is sufficient to tell whether a standard motor will meet the expected ambient temperature conditions. However, there are a few points to bear in mind.

If the motor is to operate in a normal, open atmosphere, a standard ventilated motor will most likely carry the load placed on it without exceeding the permissible temperature rise. If this same motor is placed in a restricted enclosure or in high ambient temperature, it is very possible that a prohibitive winding temperature will be reached

Table 3—Allowable Motor Temperature Rise: Continuous Ratings*

Motor Enclosure	Allowable temperature rise (C) for . . . Class A Insulation	Class B Insulation	Class H Insulation
Open general-purpose	40	..	...
Drip-proof	40**	..	...
Splash-proof protected and semiprotected, and drip-proof fully protected...	50	70	110
Totally enclosed	55	75	115
All others	50	70	110

*Based on maximum ambient temperature of 40 C. From NEMA Standards. **May also be rated for 50 C rise.

Table 4—Allowable Motor Temperature Rise: Short Time Ratings*

Motor Enclosure	Time Ratings (minutes)	Temperature rise (C) for . . . Class A Insulation	Class B Insulation	Class H Insulation
Totally enclosed	5, 15, 30, 60	55	75	115
Open	5, 15, 30, 60	50	70	110

*Based on maximum ambient temperature of 40 C and measurement by thermometer method. If resistance method, or thermocouple on the winding, is used, temperatures will be about 10 C higher. From NEMA Standards.

Table 5—Motor Service Factors*

Motor Horsepower	Service Factor — AC Motors	DC Motors
1/20, 1/12, ⅛.....	1.4	...
1/8, ¼, ⅓	1.35	...
½, ¾	1.25	...
1	1.25	1.15
1 ½, 2	1.20	1.15
3 and up	1.15	1.15

*For general-purpose and other continuous-duty motors having a rated temperature rise of 40 C. From NEMA Standards.

and serious motor damage result.

Then, too, while a totally enclosed motor may offer a few exterior design advantages, a simple product design modification — with little overall sacrifice—may permit mounting a fan or blower on the motor shaft. This slight change means a great boost in motor cooling and can lead to considerable savings in the active material in the motor and, thereby, a less expensive motor.

Other Ambient Conditions: Several other ambient conditions may have to be considered in selection or specification of a motor. Some of these conditions are listed because they can have serious adverse effects on motor performance. For a more detailed explanation of conditions to watch for in selecting a motor, see NEMA publication MG1-1955, sections 6.01 and 6.02.

HUMID ATMOSPHERES attack insulation and exposed metal parts of the motor. In extreme conditions, this can be very serious and must be counteracted by putting special materials into the motor. Humidity is but one of many corrosive atmosphere possibilities. Each must be treated as a special case. The important point to bear in mind is that a clear picture of the expected service atmosphere should be drawn before a motor is finally designed or selected.

DUSTY ATMOSPHERES have several effects on a motor. First, dust may clog ventilation openings and eventually cause thermal failure of the motor. In a single-phase motor with a centrifugal switching device, dust can accumulate in the movable parts or contacts and cause malfunction. If dust is metallic, grounding of terminals or abrasion of insulation may result. Usually, where dust is expected, the totally enclosed motor may be necessary.

EXPLOSIVE ATMOSPHERES may be encountered and, if this is the case, very special design measures must be taken to prevent an explosion in the surrounding air even if the motor has an internal explosion or burns out for any reason. Motors for these applications are a separate class. Operating requirements for these motors are outlined in the National Board of Fire Underwriters pamphlet *Standard for Electric Motors and Generators for Use in Hazardous Locations*. This subject will be discussed more fully later.

Another consideration is the altitude above sea level at which the device must operate. Air density decreases as altitudes increase, and the cooling effect of the air is decreased. Therefore, a motor with a normal temperature rise at sea level will get hotter as the altitude is increased. As a rule of thumb, for every 1000 ft of altitude over 3300 ft, the temperature rise of a motor cooled mainly by convection will increase 3 C. However, a compensating factor may exist. In general, when altitude increases, ambient temperature decreases. Total temperature is the limiting item, not temperature rise. If the calculated temperature rise of the motor increases 6 C due to altitude, but the ambient drops 6 C, the motor would run as satisfactorily as it does at sea level.

Mounting Method and Position: The position in which the motor is mounted affects the design, *Fig.* 2. Vertical shaft-down motors may have to

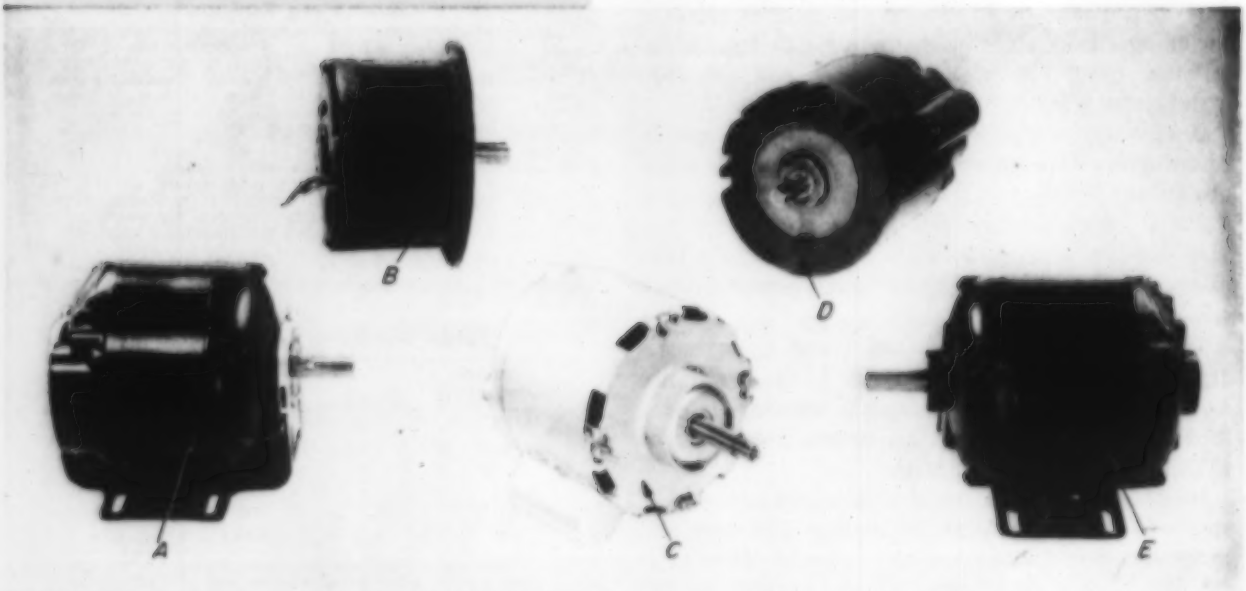


Fig. 2 — Five most common motor mountings: *A*—resilient cradle base; *B* — flange mounting with mounting holes in flange; *C* — face mounting with extended through-bolts; *D*—face mounting with mounting holes drilled and tapped; *E*—rigid mounting

be provided with special oil return systems to prevent oil leakage down the shaft. Mounting position may also influence temperature rise due to position of ventilation openings and addition of drip covers.

As a guide, here are five of the most popular methods which, with simple modification, can be adapted to almost any product design:

1. *Rigid base mounting:* In this method a base is attached rigidly to the motor frame and this base is then bolted to the device. Mounting dimensions for this type are standardized.

2. *Resilient base mounting:* This type of mounting is generally used to isolate motor vibration from the base. Resilient rings are provided between the motor and base to absorb the vibration in the motor. Mounting dimensions identical to rigid base mountings may be provided.

3. *Face mounting:* It may be practical and efficient to mount the face of the motor end bell directly onto the driven device. In this case, a closely machined rabbet is provided on the end bell to mate with a similar rabbet on the machine. Eccentricity and face wobble of the mounting surfaces are closely controlled to insure proper lineup of parts. Standards are established on rabbet diameters and bolt circles, but if conditions warrant, special diameters can be provided.

4. *Mounting from extended through-bolts:* It is often possible to mount the motor by extending the threaded portion of the bolt holding the motor together. In this case, the machine manufacturer must adapt his mounting pads to fit the motor manufacturer's bolt circle dimensions. Motor design considerations make it difficult for the motor manufacturer to vary his through-bolt circle. There is no established standard on through-bolt circle for any size of motor, and this dimension may vary considerably among motor manufacturers.

5. *Special mounting:* In some small devices, it is practical to mount the device on the motor instead of the motor on the device. Many special end bells can be provided with various mounting arrangements, and the motor manufacturer should be contacted to determine the best mounting.

Bearings: In general, small power motors can be provided with two types of bearings: oil-lubricated sleeve bearings, or grease-filled ball bearings.

Sleeve bearings are capable of carrying reasonable radial loads. If axial thrust loads are present, special thrust collar may be necessary to give satisfactory operation.

Ball bearings are capable of absorbing higher radial and axial loads.

Thermal Protection: The product and the motor should be examined from the standpoint of National Electric Code and Underwriters' Laboratories requirements. These will determine the type of thermal protection required, if any. Size and protection of associated conduits and switches can be examined from a fire hazard standpoint.

Can a Standard Motor Be Used?

With his motor needs pretty well defined, the designer is in a position to compare these needs to the standard cataloged motors available.

The task may be made easier by taking from the data the basic information regarding: power, duty, rotation, speed, torque and starting current.

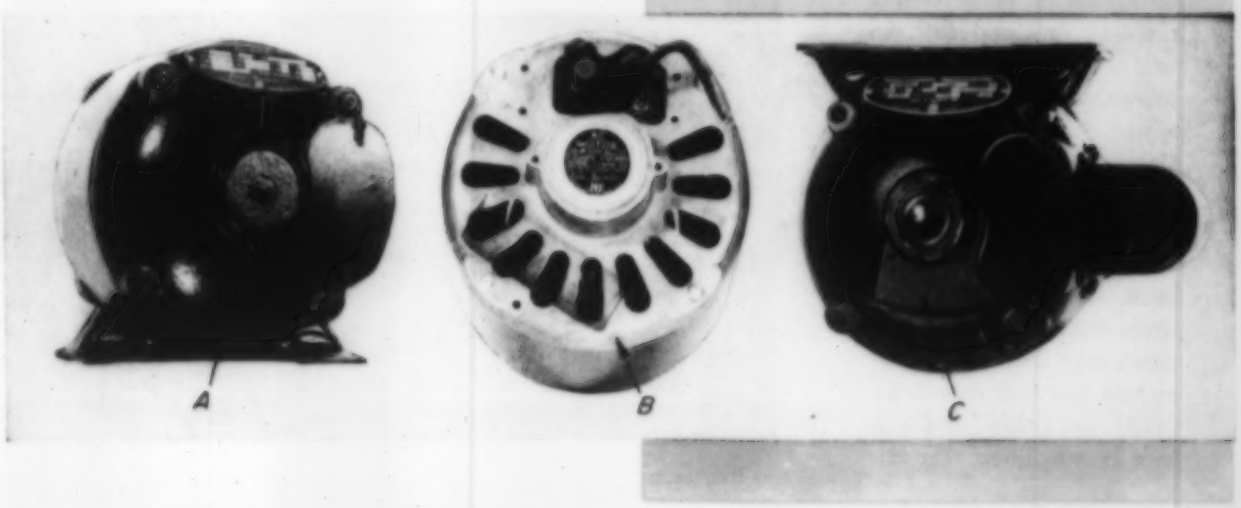


Fig. 3 — Three common motor enclosures: *A*—totally enclosed; *B* — open guarded; *C* — drip-proof (shown for ceiling mount)

For example: is duty continuous or intermittent; is rotation unidirectional, reversible at rest, or reversible at rest and rotating. With this data, a simplified table, such as *Table* 6, may be referred to, and selection of motor types narrowed to those two or three which seem best able to fill the bill.

A more comprehensive tabulation, *Table* 7, can then be used. Probably the first consideration in pinpointing of motor types should be how the various types have previously been applied, and on what devices.

From this point, the designer can proceed to study the standards governing specific aspects of his motor needs.

In the National Electrical Manufacturers Association publication MG1-1955 catalogs, the following items are standardized:

1. Voltage
2. Frequency
3. Horsepower, speed and torque ratings
4. Inrush current
5. Temperature rise
6. Enclosure type
7. Mounting dimensions
   a. Shaft diameter and extension

Potato Peeler

Mechanical Requirements: **Motor drives abrasive disk at bottom of abrasive-lined cylinder to peel potatoes fed into cylinder. Motor operates vertically, shaft up, and drives wheel through belt reduction. Lower half of machine is enclosed by sheet-metal skirt. Space is a problem, since driven pulley must be located on vertical centerline of machine; pulleys must be separated enough to provide necessary belt contact, and motor must fit within enclosing skirt.**

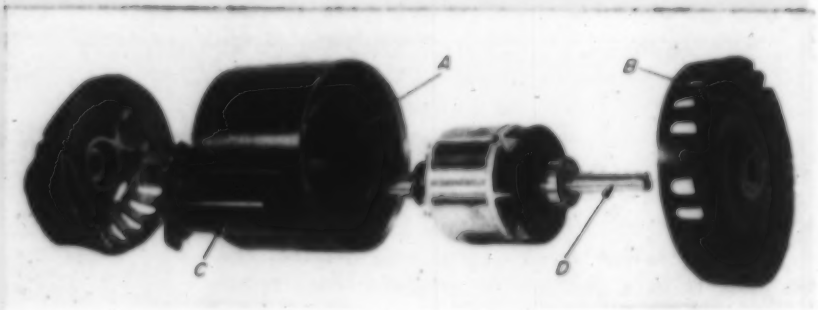
Electrical Requirements: **Even if load were constant 1/3-hp, care must be taken, since standard 1/3-hp, 40 C open motor is rated when mounted in atmospheric conditions not seriously interfering with ventilation. This motor must operate within a skirt which prevents circulation of cool outside air.**

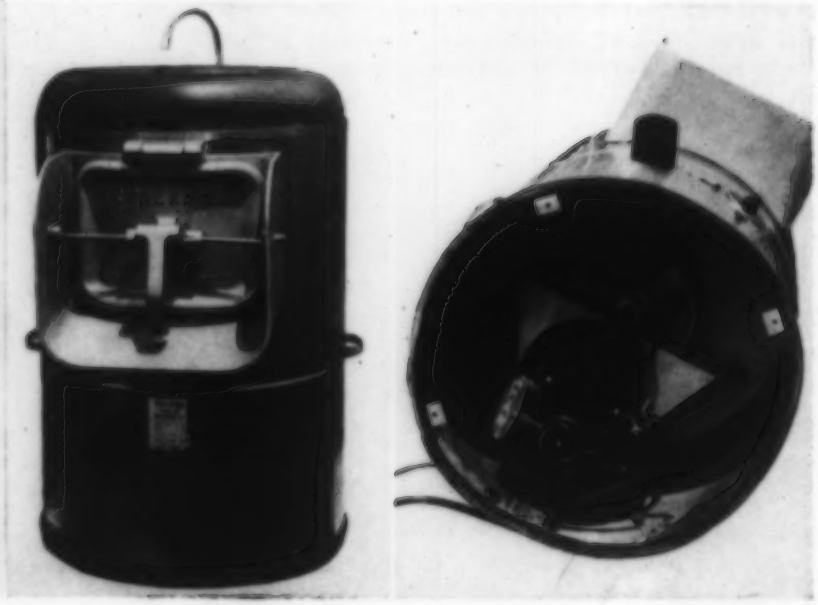
Motor Design: **Special winding and iron stack (*A*) designed to meet torque requirements and still run cool. Mounting plate is available on peeler, so motor is face mounted. Slots are provided in mounting plate to shift motor for belt tensioning. Standard NEMA C end bell used, with standard bolt-circle drilling and tapping. However, standard pilot on this end bell cannot be used, so entire end-bell face is machined flat (*B*).**

Capacitor and lead outlet (C) are positioned for proper clearance and convenience for electrical connections. Shaft is milled flat for coupling (*D*).

Motor Data: **Capacitor start, ball bearing, 1/3-hp, 1725 rpm, 40 C continuous temperature rise. Power supply: 115/230 v ac, 60 cycle.**

Company: **Toledo Scale Co.**





b. Keyway
c. Shaft center to mounting base
d. Mounting holes
e. Center of mounting hole to usable portion of shaft

As an aid, the NEMA tables on horsepower rating and temperature rise are shown as *Tables* 3 and 4. Inrush currents are shown in the footnotes to *Table* 7.

This same NEMA publication lists a number of available motor enclosures, *Fig.* 3. Comment is made here on the more common applications of these enclosures.

1. OPEN MOTOR is one having ventilating openings which permit passage of external cooling air over and around the windings of the motor. Example would be a washing machine where the motor is under the tub and enclosed so that no water will fall on it.

2. DRIP-PROOF MOTOR is an open motor in which the ventilating openings are so constructed that drops of liquid or solid particles falling on the motor at any angle not greater than 15 degrees from the vertical cannot enter the motor either directly or by striking and running along a horizontal, or inwardly inclined, surface of the machine, *Fig.* 4. Examples are furnace blowers or fans located where water would not normally splash upward into the motor.

3. SPLASH-PROOF MOTOR is an open motor in which the ventilating openings are so constructed that drops of liquid or solid particles falling on the motor or coming towards it in a straight line at any angle not greater than 100 degrees from the vertical cannot enter the motor either directly or by striking and running along a surface of the motor, *Fig.* 4.

4. GUARDED MOTOR is an open motor in which all openings giving direct access to live or rotating parts (except smooth shafts) are limited in size by the design of the structural parts or by screens, grills, expanded metal, etc., to prevent accidental contact with such parts. Such openings shall not permit the passage of a cylindrical rod ½-inch in diameter, except that, where the distance from the guard to the live or rotating parts is more than 4 inches, they shall not permit the passage of a cylindrical rod ¾-inch in diameter. Example would be any motor mounted in the open where it can be touched by hand while running.

5. WEATHER-PROTECTED MOTOR is one so enclosed as to prevent the free exchange of air between the inside and the outside of the case, but not sufficiently enclosed to be termed air-tight. Example: fans for cooling outdoor power transformers where rain, sleet or ice may fall directly on the motor.

6. TOTALLY ENCLOSED NONVENTILATED MOTOR is a totally enclosed motor which is not equipped for cooling by means external to the enclosing parts. Examples: meat slicers, food choppers, etc., where the motor is an external part of the machine.

7. TOTALLY ENCLOSED FAN-COOLED MOTOR is a totally-enclosed motor equipped for exterior cooling by means of a fan or fans integral with the motor itself but ex-

Table 6—Motor Type Selection Chart

Motor Type ——→	Split-Phase	Shunt or Compound	Universal	Polyphase Induction	Synchronous	Synchronous Polyphase	Synchronous Capacitor	Shaded Pole	Universal Governed	Capacitor	Capacitor Start
Current Supply											
Ac	X			X	X	X	X	X		X	X
Dc		X									
Ac or Dc			X						X		
Duty											
Continuous	X	X		X	X	X	X	X		X	X
Intermittent			X						X		
Rotation											
Unidirectional								X	X		
Reverse at rest	X				X	X	X				X
Reverse, rest or rotating		X		X						X	
Speed											
Constant, fixed	X			X	X	X	X	X		X	X
Constant, adjustable		X							X		
Varying			X								
Starting Torque											
Low							X	X		X	
Normal	X				X						
High		X	X	X		X			X		X
Starting Current											
Low							X	X		X	
Normal	X	X	X	X	X	X			X		X

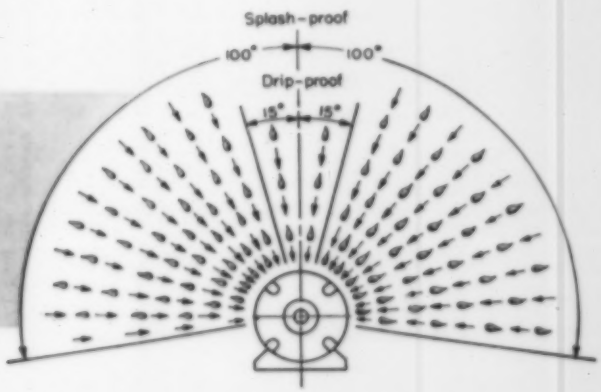
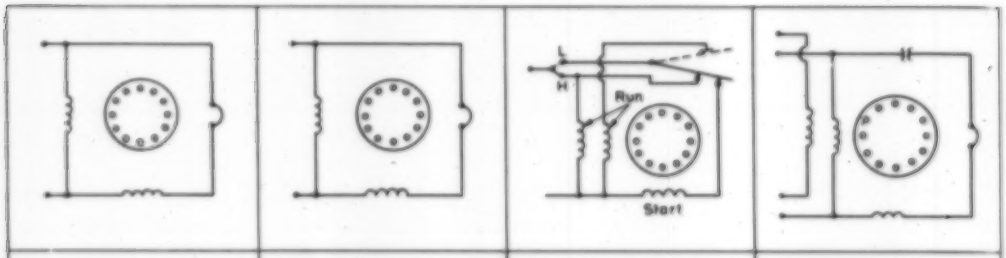
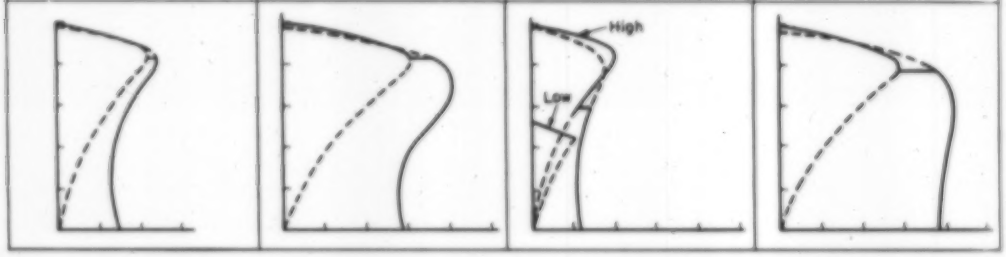


Fig. 4—Limitations of splash-proof motor and drip-proof motor protection from water droplet entry into motor

Table 7a—AC Fractional and Subfractional-

	Single-Phase Motors			
	SPLIT-PHASE TYPES			CAPACITOR START
	General Purpose	High Torque	Two-Speed Pole-Changing	
Connection Diagram[2]				
Speed-Torque Curves[3] (characteristic)				
Rotor Construction	Squirrel cage	Squirrel cage	Squirrel cage	Squirrel cage
Starting Method (built-in)	Centrifugal switch	Centrifugal switch	Centrifugal switch	Centrifugal switch
Horsepower Ratings (common)	1/20–1/3	1/6–1/3	1/8–3/4	1/8–3/4
Full-Load Speeds (common; 60 cycles)	3450, 1725, 1140, 865	1725	1725/1140, 1725/865	3450, 1725, 1140, 865
Speed Classification	Constant	Constant	Two-Speed	Constant
Speed Control Method			Two-speed switch	
Torque				
Locked Rotor	Moderate	High	Moderate	Very high
Breakdown	Moderate	High	Moderate	High
Radio Interference				
Running	None	None	None	None
During Acceleration	One click	One click	Two clicks	One click
Cost Comparison (for same hp)				
Below 1/20-hp				
1/20 to 1/4-hp	100	75	210	125
1/3 to 3/4-hp	80	54	150	100
Notes and Typical Applications	For constant-speed operation, even under varying load conditions. Where moderate torques are desirable or mandatory, this type is often used in preference to the more costly capacitor-start motor. Meets NEMA starting currents. Typical applications: blowers; centrifugal pumps; duplicating machines; refrigerators; oil burners; unit heaters.	High locked-rotor currents (in excess of NEMA) limit use of this type on lighting circuits to applications where the motor starts only very infrequently, because of a tendency to cause flickering of lights. Principal applications: washing and ironing machines; cellar-drainer pumps; home workshop tools.	Used where two definite speeds independent of load are required. Ratings above ¾-hp usually made capacitor-start. Motor shown always starts on high-speed connection; transfer to low speed made by starting switch. Common applications: belted blowers for warm-air furnaces or for other purposes; attic ventilators; air-conditioning apparatus.	General-purpose motor suitable for most applications requiring constant speed under varying loads, high starting and running torques, high overload capacity. Also available as two-speed pole-changing motor above ¾-hp. A few important applications are: refrigeration and air conditioning compressors; air compressors; stokers; gasoline pumps.

Horsepower Motors[1]

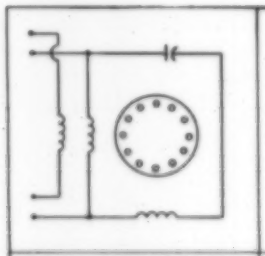
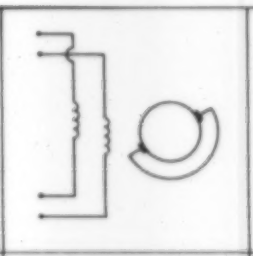
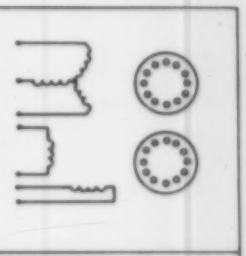
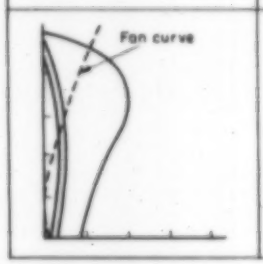
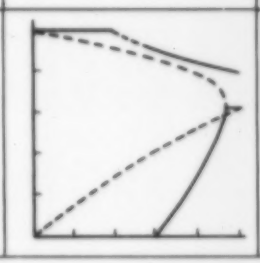
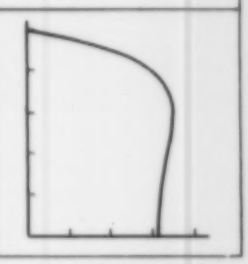
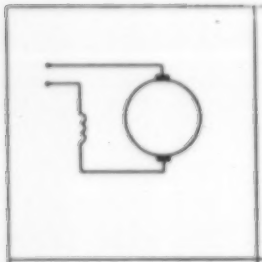
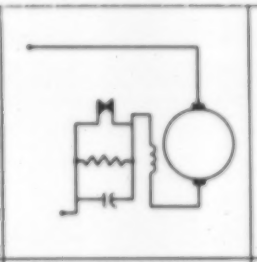
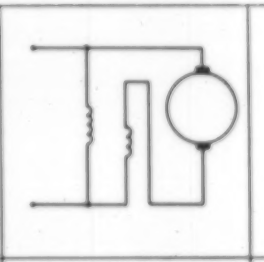
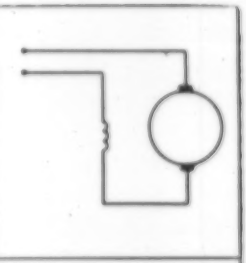
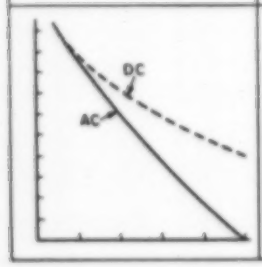
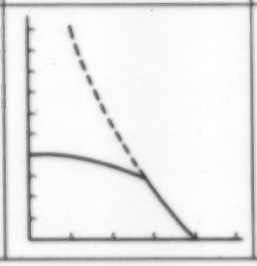
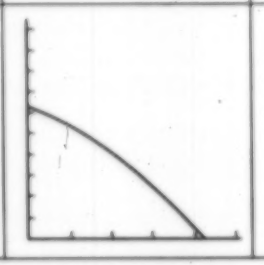
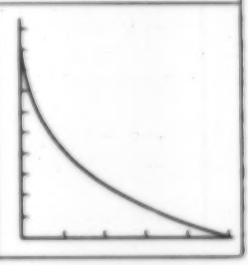
Single-Phase Motors			1, 2 or 3-phase	Polyphase
PERMANENT SPLIT CAPACITOR	**REPULSION START**	**SHADED POLE**	**NONEXCITED SYNCHRONOUS (Reluctance)**	**SQUIRREL CAGE INDUCTION**
			Stator winding may be: split-phase; capacitor-start; capacitor; polyphase	
				
Squirrel cage	Drum-wound, commutator	Squirrel cage	Cage, with cutouts	Squirrel cage
None required	Short-circuiter	None	Depends on stator winding	None
1/20–3/4	1/8–3/4	1/2000–1/20	1/3000–1/3	1/6–3/4
1620, 1080, 820	3450, 1725, 1140, 865	1450–3000	3600, 1800, 1200, 900	3450, 1725, 1140, 865
Constant, or adjustable varying	Constant	Constant, or adjustable varying	Absolutely constant	Constant
Two-speed switch or autotransformer	.....	Choke or resistor	.....	.....
Low Moderate	Very high High	Low Low	Low Moderate	Very high Very high
None None	None Continuous	None None	None	None None
.....	.....	100	.....	.....
140 100–110	128 100	.....	200–400 275	165–195 100
Primarily used for unit heaters, or for other shaft-mounted fans. Essentially a constant-speed motor, but by means of a two-speed switch, or by means of an autotransformer, other speeds can be obtained, with fan loads, if horsepower rating selected closely matches the fan load. Can also be made in intermittent ratings for plug-reversing service.	Constant-speed motor suited to general-purpose applications requiring high starting torque, such as pumps and compressors. An associated type, the repulsion-induction (buried cage) is used for door openers and other plug-reversing applications. Has been displaced for many applications by the capacitor-start motor.	For ratings below 1/20-hp, this is a general-purpose motor. For fan applications, speed control is effected by use of a series choke or resistor. Applications: fans; unit heaters; humidifiers; hair driers; damper controllers.	Cutouts in rotor results in synchronous-speed characteristics. Curve shown is for split-phase stator. Pull-in ability is affected by inertia of connected load. Used for teleprinters, facsimile-picture transmitters, graphic instruments, etc. Clocks and timing devices usually use shaded-pole hysteresis motors rated at a few millionths of a horsepower.	Companion motor to capacitor-start motor with comparable torques, and generally suited to same applications if polyphase power is available. Inherently plug-reversible and suitable for door openers, hoists, etc. High-frequency motors used for high-speed applications, as for woodworking machinery; rayon spinning; and portable tools.

Table 7b—DC and AC-DC Fractional and Subfractional-

	AC or DC (60 cycles or less) — UNIVERSAL		Direct Current	
	Without Governor	With Governor	SHUNT OR COMPOUND	SERIES
Connection Diagrams[1]				
Speed-Torque Curves[2] (characteristic)				
Rotor Construction	Drum-wound, commutator	Drum-wound, commutator	Drum-wound, commutator	Drum-wound, commutator
Starting Method (built in)	None	None	None	None
Horsepower Ratings (common)	1/150-1	1/50-1/20	1/20-¾	1/25-1/30
Full-Load Speeds (common)	3000-11,000	2000-4000	3450, 1725, 1140, 865	900-2000
Speed Classification	Varying, or adjustable varying	Adjustable	Constant, or adjustable varying	Varying, or adjustable varying
Speed Control Method	Choke or resistor	Adjustable governor	Armature resistance	Resistor
Torque: Locked Rotor	Very High	Very high	Very high	Very high
Radio Interference				
Running	Continuous	Continuous	Continuous	Continuous
During Acceleration	Continuous	Continuous	Continuous	Continuous
Cost Comparison (for same hp)				
Below 1/20-hp	75	110		185
1/20 to ¼-hp.	105-175	140-160	175-225	...
⅛ to ¾-hp	...	...	120-140	...
Notes and Typical Applications	Light weight for a given output, high speeds, varying-speed and universal characteristics make this type very popular for hand tools of all kinds, vacuum cleaners, etc. Ratings above ¾-hp usually compensated. Some speed control can be effected by resistor or by use of tapped field. Used with reduction gear for slower speed applications.	By means of a centrifugal governor, a constant-speed motor having the advantages of the universal motor is obtained. Governor may be single speed or adjustable even while running. Speed is independent of applied voltage. Used in typewriters; calculating machines; food mixers; motion-picture cameras and projectors; etc	A constant-speed companion motor for the capacitor-start or split-phase motor for use where only dc power is available. For unit-heater service, armature resistance is used to obtain speed control. Not usually desired for field control	Principally used as the dc companion motor to the shaded-pole motor for fan applications. Used in these small ratings in place of shunt motors to avoid using extremely small wire

Horsepower Motors[1]

Footnotes to Tables 7a and 7b

1. **Standard Conditions:** Ordinarily designed to operate in ambient temperatures from 10 to 40 C (50 to 104 F). Allowable line-voltage variations, ±10 per cent; allowable frequency variations, ±5 per cent. Locked-rotor currents for single-phase motors (except split-phase high torque, and synchronous types) usually do not exceed following NEMA limits:

Rating (hp)	Locked-Rotor Current (amp) at . . . 115 v	230 v
1/6 and smaller	20	10
1/4	23	11½
1/3	31	15½
1/2	45	22½
3/4	61	30½

Fractional-hp motors are built for across-the-line starting. Standard rotation direction is counterclockwise facing the end opposite the shaft extension.

2. **Diagrams:** Arrangements are typical or representative. Many others are possible.

3. **Speed-Torque Curves:** Each abscissa division=100 per cent of full-load torque. Ordinates are speed: for all ac motors, 1 division=20 per cent of synchronous speed; for universal motors, 1 division=1000 rpm; for dc motors, 1 division=20 per cent of full-load rpm.

Tables adapted from: A. E. Knowlton—*Standard Handbook for Electrical Engineers*.

ternal to its enclosing parts. Example: woodworking equipment where it would be possible to have large amounts of sawdust around or on the motor.

8. EXPLOSIONPROOF MOTOR is a totally enclosed motor whose enclosure is designed and constructed to withstand an explosion of a specified gas or vapor which may occur within the motor casing. Example: gasoline dispensing pump motors.

In addition to these general-purpose standards, a group of definite-purpose motors have been established as standard because of their extensive use. These motors are for:

1. Hermetic refrigeration condensing units
2. Belt-drive refrigeration compressors
3. Jet pumps
4. Shaft-mounted fans and blowers
5. Belted fans and blowers
6. Stokers
7. Cellar drainers and sump pumps
8. Gasoline dispensing pumps
9. Oil burners
10. Home laundry equipment
11. Coolant pumps
12. Deep-well pumps (submersible motor)
13. Elevators
14. Cranes
15. Woodworking and machine tools (shell type motors)

Also included in the definite-purpose motor category are universal motor parts (stator, rotor and brushholder mechanism).

These motors are variations of general-purpose designs that make the motor more adaptable to a specific application. In some cases, mounting dimensions and methods are changed from standard; in others the variation may be enclosure, performance, inclusion of switches, or addition of inherent overheating protection.

If the motor is to operate in an unfavorable atmosphere, the designer may want to review Article 500 of the National Electric Code which classifies hazardous locations of various types. It may also be a good idea to review any of the National Board of Fire Underwriters Standards which may apply to his product from a motor standpoint. The following standards may be of interest in specific cases:

1. Standard for Motor Operated Appliances
2. Standard for Industrial Control Equipment
3. Standard for Air Conditioning, Commercial, and Domestic Refrigeration Equipment
4. Standard for Motors and Generators for Use In Hazardous Locations

After examining the standards literature, the designer will find himself facing one of four situations:

1. Standard motors fit the product perfectly, in which case he is now in a position to select a motor.

2. Standard motors almost fit the product, but need minor modifications.

3. Standard motors fit the product, but some additional product features can be obtained if modification is made. Thus, the motor may enter the definite-purpose class.

4. Standard motor will not do without major modifications, in which case: (1) the basic product design can be modified, perhaps sacrificing product features, to come closer to a general-purpose motor; or (2) the product design can be retained and a special motor design called for.

If the design falls into any of the last three classes, as complete a specification sheet as possible should be made up.

What Modifications are Needed?

In every case, the designer should tabulate his motor requirements. The importance of this step increases sharply when motor requirements exceed existing standards or are not covered by standards. A typical motor-application check list is shown as *Table* 8.

If the check list of motor requirements falls in line with a standard motor, the designer's selection of a motor is done.

If, however, the motor is to differ from standard—dimensionally, electrically or esthetically—a special motor must be designed.

From this point, the problem is the motor supplier's. But the designer should try to be aware of what motor modifications the specifications call for. Only in this way will he be able to save valuable development time and control motor costs. If the design requires too special a motor, simple product design changes can perhaps be made to bring motor costs back to a more practical level.

An understanding of modifications should be of help, as well, even when a standard motor is ad-

equate. A simple, inexpensive modification to that standard motor may give the product important sales features.

Motor elements most commonly affected in the design of special motors are: (1) stator, (2) rotor, (3) shaft, (4) end bells, (5) wiring, and (6) terminal connections.

Stator: Most often, from the standpoint of the designer, the stator enters in when specific motor shapes are desired. Here, the possible relationships between stator OD, rotor OD and rotor bore size are involved.

It is possible to obtain the same output in a motor throughout wide variations of length to diameter ratios, *Table* 9. Motors having *L/D* ratios higher than 4/1 have been built, and it is possible to bring the *L/D* ratio down as low as 1/8.

For high-production work, motor manufacturers usually have three or four outside-diameter punchings to work with. High-cost progressive dies have been made to produce these punchings. If the OD of a punching must be changed, there must be sufficient volume in the product to justify a new die. It is sometimes possible, using low-cost notching dies, to produce limited quantities of a new punching. No standard for punching dimensions exists in the industry and, in general, the designer cannot interchange stators from one manufacturer to another without dimensional discrepancies occurring.

There are manufacturing limitations to an extremely large *L/D* ratio. Basically, it is difficult to produce a long, narrow stack of sufficient rigidity. Furthermore, since the stator coils must be inserted through the stator bore, winding becomes a problem. The designer must expect to pay a price penalty if his application demands a high *L/D* ratio. In general, a long, narrow motor is harder to cool than a short, flat one, so increased ventilation must also be provided.

TABLE 8—MOTOR APPLICATION CHECK LIST

PRODUCT DEFG LAWN MOWER

	MEETS STANDARDS	EXCEEDS STANDARDS	NOT COVERED BY STANDARDS	DETAILS
Mounting: Rigid				
Resilient				
Face				
Flange			X	10-32 NF2B-3/4" long
Extended Bolts			X	#3 Woodruff Key on 5/8" diam. Shaft and 2 x 3/4 extension on opposite end for rotation indicator
Shaft Extension				
Rotation	X CCW			
Torque Characteristics: Running	X			
Starting	X			Must accelerate load without blowing 20 A fuse
Braking	None			
Inertia	Motor drives a 24 x 2 x 1/4 steel blade at 3600 rpm			
Loading: Radial	X			(no appreciable loading)
Axial	May encounter some axial shocks			
Ventilation: Ambient Temperature	X			
Restricted Enclosure			X	Drip cover over front end bell
Fan-Cooled	No			
Vibration	Normal			
Noise Level	X			General noise level of g.p. motor acceptable
Weight	X			
Terminal Location: Conduit Box	#16 2-cond cord, 20" long			
Leads Out				
Contour	Smooth & eye-appealing			
Finish	Silver gray			

An extremely low L/D ratio also entails a cost increase. Large end bells must be provided to house the machine, more end-turn windings that increase losses must be added. Extremely short, flat stacks also become less rigid, and reinforcing is necessary.

In general, L/D ratios between 1/6 and 1/1 are the most practical.

Aside from L/D ratios, other stator modifications are: iron content, copper content, winding and insulation. Regarding these, the final decision should be made by the motor manufacturer. But, familiarity with these points will help a designer follow through a motor development and justify his decisions and costs to his own company.

IRON CONTENT: Iron in the stator governs the torque rating and efficiency of the motor. The stator must carry the magnetic flux of the motor, and this flux, acting with the rotor current, produces torque. Volume of iron in the stator determines the flux—more iron, more flux.

While electrical losses occur in iron, a motor with more iron will actually be more efficient. More iron not only reduces electrical losses, but it also provides greater outlet for heat. And because heat, in the final analysis, is the principal influence on efficiency, the improved cooling more than offsets the electrical losses.

The precise volume of iron to be used is determined not only by the torque and efficiency desired, but also by the grade of iron used and, to a degree, the maximum motor weight allowed. Iron grades range from common iron to armature and dynamo grades. Prices go up for the higher grades, but their use lowers losses, increases efficiency, and helps keep weight down.

COPPER CONTENT: Current flowing in a wire produces heat. If more copper area is added, less heat is produced. This automatically increases machine efficiency. Other factors affected by increases in copper cross-section are:

1. Increased breakdown torque
2. Increased running speed
3. Reduced I^2R loss.

Actually, the only major reason for considering a reduction in copper content is to reduce motor costs. In some instances, copper reductions can be serious in that they make longer iron stacks necessary to offset adverse magnetic effects.

WINDING: The iron in a motor will operate satisfactorily over a wide range of magnetic densities. Because tooling is available for certain punchings and preferred stacking lengths, the motor manufacturer will generally vary number of turns, wire size, or start and main-winding relationships to produce more running torque, higher running speeds, more starting torque or less temperature rise.

INSULATION: If extreme moisture is expected, one or two dips and bakes a moisture-resisting varnish should be applied to the stator. Anti-fungicides can be added to prevent fungus growth in tropical climates.

If severe temperatures are encountered in the application, several classes of insulation are available for various temperatures—Class A for 105 C, Class B for 130 C, and Class H for 180 C. These temperatures are the temperatures ultimately attained by the insulated parts, and do not refer to the ambient temperature. The limits are selected to give long trouble-free service.

Rotors: Two obvious limitations govern rotor modifications: (1) the rotor must fit into the stator bore and be as long as the stator, and (2) the rotor bore must be sufficiently large to permit the insertion of a shaft big enough to carry the load.

Generally, not too many rotor variations are made. A change to accomplish a particular performance characteristic is frequently offset by a loss of some other equally important characteristic.

In extreme cases, special rotors can be evaluated to improve starting torque, inrush current or speed characteristics, or to attain unique performance requirements. A recent example is a motor for a circulating pump. In this pump, the impeller is attached to the face of the rotor. The fluid passes through the rotor. Designwise, the rotor bore had to be large enough to pass the required amount of fluid. This meant a completely new lamination design, a quite expensive item.

Three types of rotors are generally built:

1. *Cast-Aluminum Bars:* Rotor punchings are assembled together and molten aluminum is forced through the slots. End rings are cast integrally with the bars. This integrated assembly serves as the squirrel cage or conducting circuit of the rotor. These rotors are easy to mass produce and are practically indestructible.
2. *Solid-Copper Bars:* Construction is the same as the cast aluminum, except that solid-copper bars approximately the shape and size of the rotor slot are used. In some constructions, the bars are extended beyond the iron, then bent over and brazed together to form the end ring
3. *Wound Rotor:* This construction is used in some

Table 9—How Motor Shape Affects Design[1]

Length-Diameter Ratio	3:1	1:1	0.75:1	0.375:1
Length (inches)	10.0	5.75	4.25	2.75
Diameter (inches)	3.33	5.75	5.67	7.33
No. of Punchings	400	300	170	110
Radiation Area (sq in.)	130	150	140	150
Amount of Cooling Air[2]	1	5.2	5	11
Ease of Winding	Very difficult	Fairly difficult	Easy	Easy
Rotor Casting (aluminum)	difficult	Fairly difficult	Easy	Easy
End-Bell Weight[3]	1	2.5	3.25	5.0

[1]Based on 1-hp, 1800-rpm, single-phase induction motors having virtually same electrical performance.
[2]Relative. Based on fan the same size as the punching OD.
[3]Also good indication of relative end-bell cast.

polyphase induction motors. In this construction, a winding is added to the rotor slots. This winding is similar to the stator winding. The ends of the winding are brought out to slip rings. By use of external resistors, adjustable speeds may be obtained with this rotor design. A wound rotor of a somewhat different type is used on the single-phase, repulsion-start, induction-run motor to obtain the necessary starting and running characteristics. Also included in this category are rotor designs for universal and dc motors, which consist of a wound armature plus commutator.

Because of the sensitivity of rotors, their construction for any particular application should be decided by the motor supplier.

Shaft: The motor element most generally not

Floor Polisher

Electrical Requirements: **Motor drives 12-inch brush through gear reduction at 173 rpm speed. Load on brush varies with: machine weight, type of brush bristle, floor condition, flooring material, and consistency and amount of wax. Running torque must prevent motor stalling. Starting torque must accelerate brush to running speed under low-voltage condition. Machine requires 50 feet of cord.**

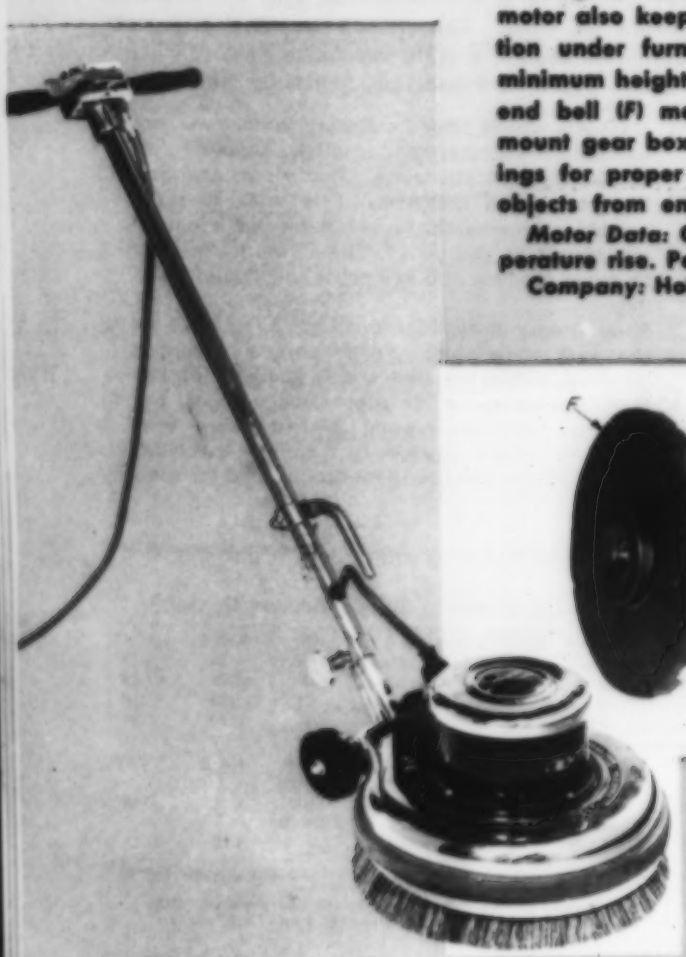
Mechanical Requirements: **Motor must operate vertical shaft down and have ball bearings. Pulley end bell must have flat surface to mount gear box. Gear box has no cover plate; motor end bell serves as cover plate. Motor shaft (*A*) must be machined to mount pinion held by key. Machined hub, concentric with the shaft, must extend from the end bell to serve as pilot for gear box. Cord and plug must be brought out of motor frame. Falling objects must not enter motor enclosure.**

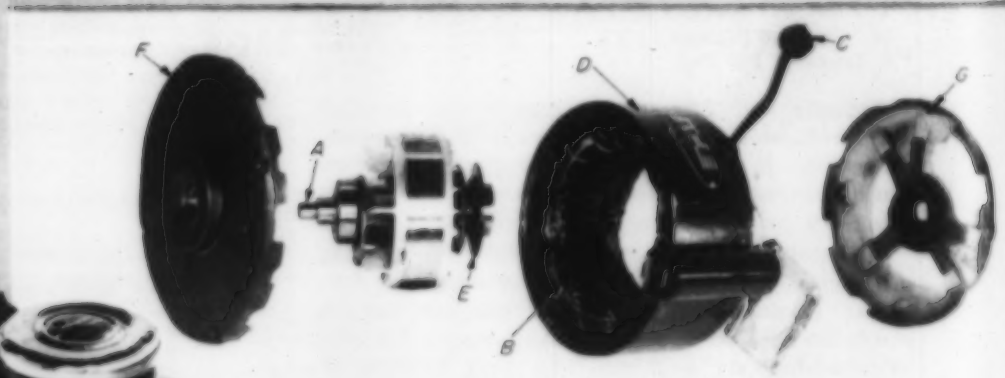
Motor Design: **Electrically, the motor meets NEMA standards, but top NEMA performance must be supplied, requiring special winding (*B*). Special cord and plug (*C*) match connector on machine.**

Prime consideration is appearance. To blend with large brush housing, a motor with low *L/D* ratio was developed (*D*). Low-height motor also keeps machine height at minimum, permitting easy operation under furniture. Special end bells have smooth exteriors and minimum height. Special low-height centrifugal switch (*E*). Drive-side end bell (*F*) machined flush; mounting holes drilled and tapped to mount gear box. Switch end bell (G) provided with ventilation openings for proper cooling. Drip cover recommended to prevent falling objects from entering motor. Motor finished in special bright color.

Motor Data: **Capacitor start, ¼-hp, 1725 rpm, 50 C continuous temperature rise. Power supply: 115 v ac, 60 cycle, single phase.**

Company: **Holt Mfg. Co.**





covered by a standard is the shaft extension. In reality, it is probably the easiest and least expensive item for any manufacturer to change. Shaft diameter standards of NEMA are usually sufficient to carry safely the maximum load that any motor could deliver in a specific frame size. Consequently, it is unusual to want a shaft extension diameter larger than standard. However, if such is the case, the designer should bear in mind that a diameter larger than standard will increase bearing sizes. These, in turn, affect the end-bell casting. The larger diameter may also affect the size of the shaft through the rotor, which would mean a new rotor punching. All of these effects would mean cost increases.

Among the shaft extension changes which can be easily made are:

1. Smaller diameter than standard
2. Longer or shorter length than standard
3. Addition of Woodruff key slot
4. Ground tapers
5. Milled flats
6. Threads
7. Special material to prevent corrosion
8. Special hardness.

End Bells: A wide variety of end bells is usually available as "standard" items with any manufacturer. Attempt to specify from this variety for reasons of economy. The economics of end bells are covered later.

Terminals and Line Connections: Leads may be brought out of the frame in almost any position. Generally, a two-conductor cord is used for this purpose. A conduit box can be added to the frame if more than two leads must be brought in. On fractional-horsepower motors, the most common location for the lead opening is on the right side of the nondrive end bell (viewed from the nondrive end of the motor).

Are the Modifications Economical?

Motor modifications should be viewed in the light of costs. If the features imparted to the product by the special motor give it a sales edge, then the motor costs become a secondary consideration. If, however, the features are of questionable competing value, then it may be wise to modify the basic product design to limit the number of

Fig. 5 — "Stock" special end bells. Most manufacturers have a variety of designs available, which should be reviewed before a new "special" is called for

motor changes to the least expensive total.

To list costs precisely is impossible. Each design project is distinct, and so are each manufacturer's costs. It is advisable to check with several motor manufacturers before deciding on a special motor design. A motor that one company can produce at only a high price may be supplied by another at a more reasonable cost.

Facilities of some manufacturers will permit the production of motors with simple modifications in lots as low as 10 units. In most instances, however, where lots of less than 200 are required, it is best to design a product around a standard motor.

STATOR: Some of the cost elements of stators were pointed out earlier. Extreme L/D ratios should be avoided, the most practical range being from 1/6 to 1/1. However, L/D ratios higher than 4/1 and as low as 1/8 have been produced.

Stator windings can readily be engineered to improve starting torque, running torque and speed characteristics, and also to lower temperature rises. Calculations to make a winding meet special conditions are not extremely difficult. Machines to wind motors can be varied to produce windings of different turns and wire size. Generally, medium-sized lots (200) will justify special windings.

END BELLS: Many end-bell designs are available, *Fig.* 5, and it is most economical to select from these. But if, a designer desires a special end bell, he should remember these points:

1. For sampling and low production volumes, wood patterns can be made successfully.
2. For somewhat higher production orders, machined metal match plates can be made for a few hundred dollars.
3. For large production quantities, die castings will prove the most economical. Die-casting molds cost between $5000 and $10,000. Quantities should be high enough to write this cost off within a reasonable period.

In estimating any special end-bell costs, it should be remembered that considerable tooling costs above the initial pattern or mold costs will probably be involved.

ROTORS: Generally, only three factors will economically justify special rotors: (1) large production quantities, (2) required performance characteristics that can be obtained only with special rotors, and (3) exceptional product design opportunities with special rotors.

SHAFTS: Special shafts are inexpensive unless special materials are involved. Quantities from 100 to 1000 are feasible. Some manufacturers may be able to handle even smaller lots economically.

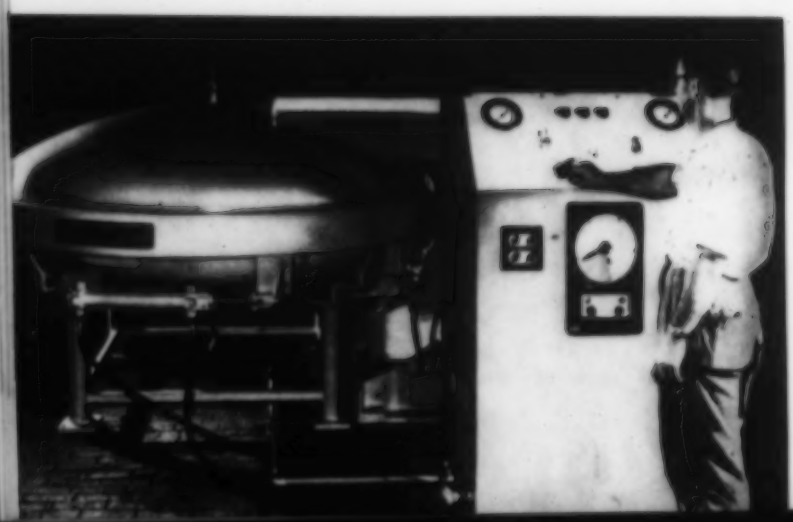
WIRING: Dual-voltage motors are somewhat more expensive than single voltage because an additional winding must be inserted in the slots.

MOUNTINGS: Special mountings are relatively inexpensive if the designer stays within the mounting methods outlined previously. Base location and capacitor location can be changed without trouble.

TERMINALS AND CONTROLS: Generally special terminal locations involve the frame and can be costly unless quantity is involved. Control switch mounting is relatively inexpensive if, for example, there is sufficient room inside the motor so that a drilled hole is all the extra machining necessary to mount the switch.

Contemporary Design

Autoclave Is Automatic



FULLY automatic operation for the first time is claimed for a new autoclave made by Philips & Davies Inc. Opening and closing of the lid are performed by a hydraulic system which is controlled by a cycle timer. Pressure and temperature are automatically maintained at correct preset values during heating, curing and cooling cycles. Additionally, a chart recorder provides a record of the complete cycle. Although all operations are fully automatic, manual controls are provided to allow removal of parts being processed in the event of a power failure.

Sintered-Metal Friction Materials

By Howard B. Huntress
Director of Research
Sintermet Div.
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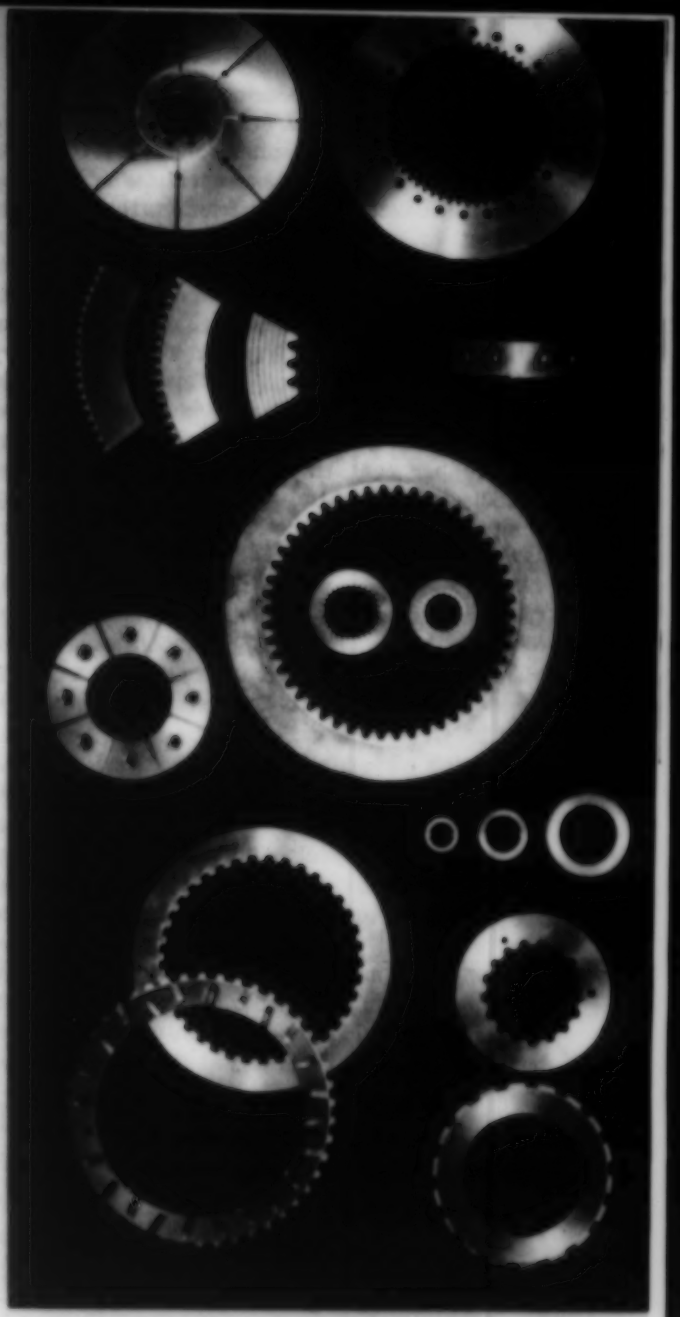
Mahwah, N. J.



Friction materials vary widely in composition and characteristics. Both metallic and nonmetallic facings have been developed and offer a range of special properties to meet the unique requirements of friction applications. In this, the second article of a group dealing with friction and its effects, sintered-metal materials and the considerations influencing their manufacture, design and application are discussed.

An earlier article ("Friction Fundamentals," July 1955) has covered the nature of friction and its effects. Other subjects to be treated include nonmetallic friction materials and the major friction devices, clutches and brakes.

NOT MANY years ago machines turned at relatively low speeds under light loads. Clutches and brakes employed friction surfaces primarily of wood, fabric, leather, cork, or hemp. If slipping was minimized and the service was not too severe, the temperature of the engaging surfaces could be kept below the charring point of the organic material, and good life could be expected. Even if the material wore out, the cost of replacement was low, and there was little need for more durable clutch materials.

As speeds and loads on machines increased, however, there was a stimulus to develop new friction materials capable of more severe service. Development of resin-bonded molded and woven friction materials was an important step in this direction. At about the same time molded organic lining appeared, advances were being made in powder metallurgy, employing techniques that necessitated an extended development period. Sintered-metal friction materials were the outgrowth of the sin-

Fig. 1—Above—Typical friction elements made of sintered-metal materials

Table 1—Typical Sintered-Metal Friction Material

Composition	Weight (per cent)
Copper	68
Tin	8
Lead	7
Graphite	6
Silica	4
Iron	7

tered porous metal bearing. In an effort to produce better lubricated bearings, researchers added large amounts of graphite and lead to mixtures of copper and tin. It was logical for such combinations to be tested for dry friction, thus stimulating interest in metallic friction materials.

Material Composition: Today sintered metallic friction materials of varied composition and capabilities are available, *Fig.* 1. This group of friction materials is radically different from the molded materials previously in general use. The metal base is bronze, approximately 90 per cent copper and 10 per cent tin by weight. To this base is added lead, graphite, silica, and iron. A typical composition is given in *Table* 1.

Manufacturing Method: In the manufacture of friction elements from compositions such as given in *Table* 1, the powdered ingredients are carefully blended, then preformed in a mold at a relatively high pressure, about 12 tons per square inch, *Fig.* 2. Upon removal from the mold, the compact is fragile but capable of being handled. These preforms are then sintered in a furnace, *Fig.* 3. While sintering imparts body and strength to the friction material, the compact is not customarily used alone but is welded to a steel back which supplies the strength and toughness necessary for the proper functioning of the friction element. In practice, friction parts may consist either of steel cores with friction material on both sides or steel backs with friction material on one side only. The former are usually complete elements, but the latter are riveted to another assembly.

On a weight basis the composition in *Table* 1 is 76 per cent bronze, and only 10 per cent nonmetallics. When the same composition is measured by volume, the metallic matrix constitutes only 60 per cent, and the nonmetallic graphite and silica 30 per cent. The other 10 per cent is made up of metallic fillers, lead and iron, not contributing to the matrix.

The intermetallic bond is formed by diffusion of the tin in the copper. The sintering temperature (about 1400 F) is held high enough to promote complete diffusion, resulting in alpha bronze.

Bonding is initiated before sintering by the cold pressing process in which the copper and tin particles are forced together and deformed to such an extent that the ever-present oxide film is ruptured. The forces involved are sufficiently high to cause cold welding of the particles. The area of welding of the particles in this manner is very small, and the strength which can be achieved in this manner is also small. The sintering process causes a great increase in the area of these contacts, because at high temperature the mobility of the metal is high, and the surface tension forces are strong enough to cause the surface area of the voids to be decreased and the area of the welds to increase. The molten condition of the tin during the early stage of sintering is a great help in this process and rapidly promotes the diffusion of the two metals. The tin spreads over the surface of the copper, causing connections to be made between copper particles where none were before.

The microstructure of the sintered metal bears out this analysis of the mechanics of sintering. The pattern of the individual orginal copper grains can be seen distinctly, *Fig.* 4. The particles tend to be more massive than they were originally, and

Fig. 2 — Production equipment for initial processing of sintered-metal friction elements. The molded powder - metal rings are formed on the machine at right of operator and pressed on equipment at left

almost every particle is connected to some extent to at least one adjacent particle. Within the matrix the nonmetallic graphite and silica partially fill the interstices. The particles of iron are considerably larger than those of bronze and usually completely surrounded by, and partially welded to, the bronze.

Bonding Technique: One of the processes almost unique to the fabrication of sintered-metal friction materials is that of bonding the friction material to the steel back from which it receives its support. Quality of the bond, *Fig.* 4, is dependent upon several processing factors: cleanliness of the steel, sintering temperature, distribution and magnitude of pressure between the compact and the steel back, time at temperature, and the nature of the controlled sintering atmosphere which should be clean, nonoxidizing and, preferably, slightly reducing. Proof of good bond is displayed when material adheres to the steel after peeling away the steel or after bending the steel until the sintered metal shells off.

Table 2—Typical Properties of Sintered-Bronze Friction Materials*

Density	5.8 gm per cu cm
Hardness	80 Rockwell H
Tensile strength	5500 psi
Elongation	0
Modulus of rupture	14,000 psi
Compression strength	25,000 psi

*Room temperature

Table 3—Elevated-Temperature Properties of Sintered-Metal Friction Materials

Temperature (F)	Hardness (Rockwell L)	Compressive Strength (psi)	Modulus of Rupture (psi)
600	90	20,000	14,000
700		18,500	8000
800	70	15,500	6500
900		13,000	4200
1000	55	11,000	2800
1100		7000	1800

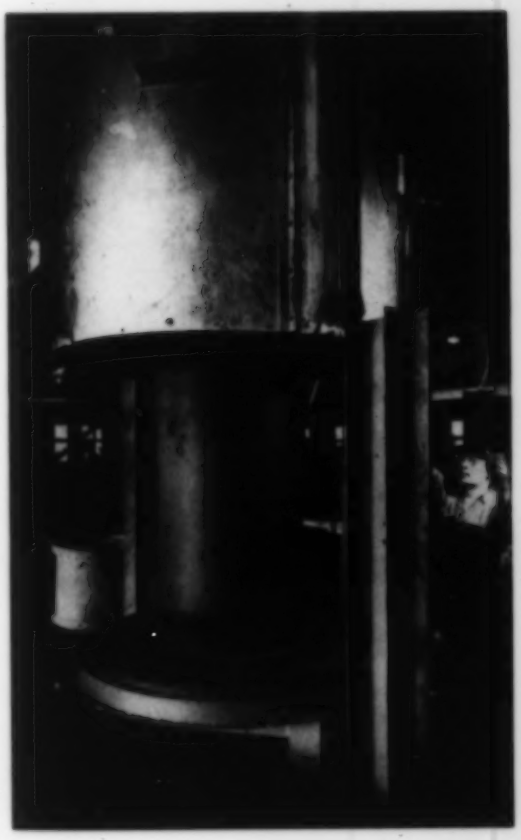
Mechanical Properties: The strength of a material containing a metallic matrix which is only 60 per cent of the total volume is considerably less than that of solid metal. The usual transverse rupture strength of sintered friction materials is about 8000 to 15,000 psi, which is not sufficient to allow the material to be used as an unsupported element. Furthermore, the material is not considered to be strong enough in thin sections to support rivets. The steel backs bonded to the friction material contribute the strength necessary to make the element useful. *Table* 2 lists the principal properties of sintered-bronze friction materials at room temperature. The effect of increasing temperature on the physical properties is shown in *Table* 3.

Surface Contamination: Operating conditions for clutch and brake friction surfaces will often vary in practice. Clutches intended to operate in a fluid medium may become dry, and those intended to operate dry may become wet with water, oil or grease. Tests on sintered-metal friction materials indicate that friction is not reduced by the presence of moisture, and some tests have shown that friction may be slightly higher when the material is wet with water than when it is dry. Grease or oil, however, reduce friction.

Continued operation with impaired friction will damage the surfaces. Lower friction causes engagement time to be lengthened and more energy must be dissipated in the clutch as heat. Although such heat breaks down the undesirable oil coating and thus tends to overcome the low friction condition, it generally produces a carbonaceous film which still tends to keep the friction level too low

Temperature Resistance: In the search for more effective friction materials, attention has been directed toward heavier-duty service at higher operating temperatures. Among the advantages of sintered-metal friction materials is that of good

Fig. 3—Sintering furnace unit in which powder-metal compacts are heated to produce intermetallic bond



temperature stability. Even though friction tends to decrease and wear to increase with rising operating temperature, the wear rate will not become exponentially greater at a particular temperature because there is no sudden breakdown of the material. Temperature characteristics of a typical material are shown in *Fig.* 5.

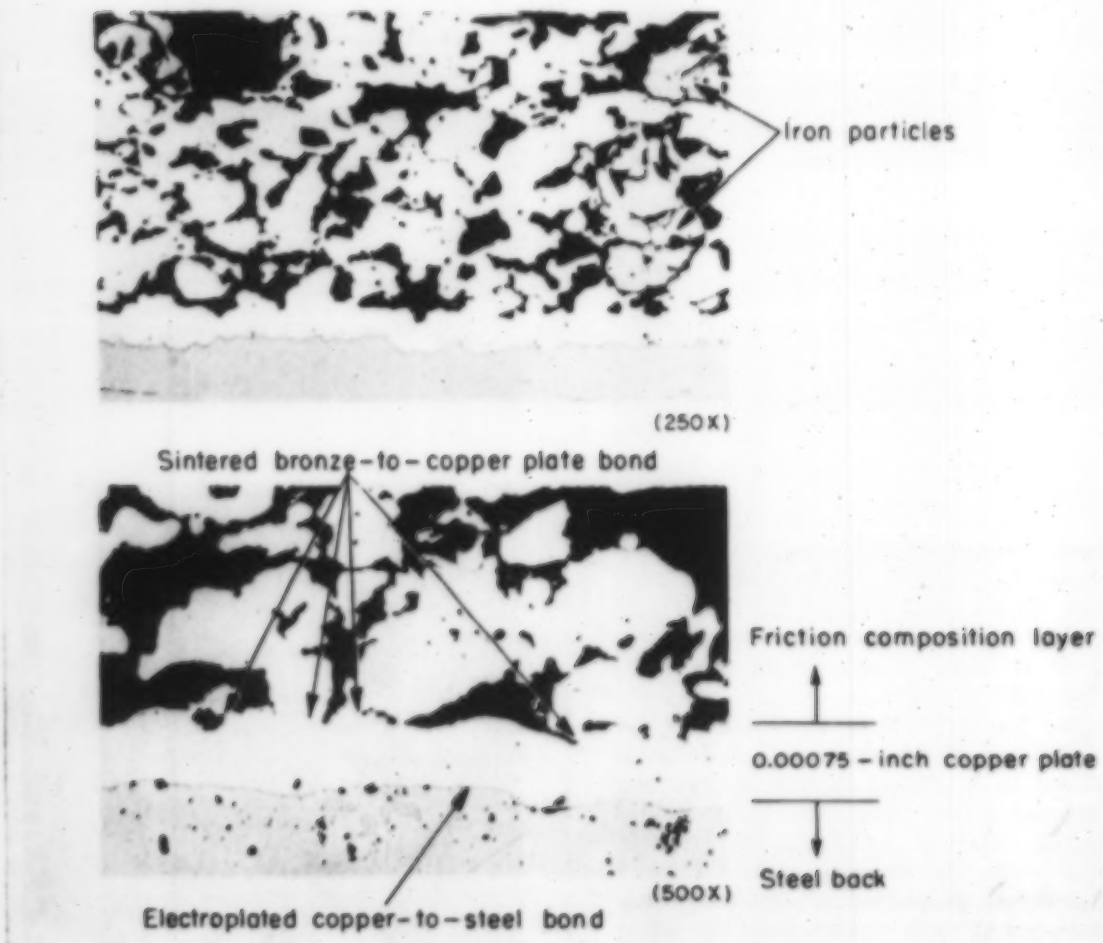
The obvious operational limitation of sintered materials is the melting temperature of the base or matrix metal. Sintered metal has been observed functioning effectively at lining temperatures of 1500 F, with low but useful friction and high but tolerable wear rate.

Mating Surfaces: Perhaps too little attention is paid to the type of material used in the surfaces against which friction materials operate. However, the choice is dictated mainly by economics, and partly by size and shape. For example, cast iron is advantageous in the mating faces for tractor master clutches, where the pressure and flywheel plates are large and thick and, thus, easily cast. In such cases a further advantage is found in the smooth action of the friction facings against the cast iron, a result which is said to be due to the presence of free graphite in the iron.

On the other hand, multiple-disk clutches and brakes, which are expected to be as compact as possible, are not particularly good applications for castings. Mating disks are sheet steel stampings when used between two friction disks, and castings or forgings when used in the end positions. When the multiple-disk mechanism is to be operated as a brake, where high temperatures are likely, the steel mating disks may be plated with chrominum which has the effect of reducing oxidation of the steel and preventing the buildup of undesirable films.

One of the bad effects of friction on heavy cast-iron plates is heat checking, which begins as minute surface cracks and may progress to the point of causing failure of the casting. Since replacement of such castings is rather expensive, one tractor company utilizes replaceable wear plates, made of

Fig. 4—Typical sintered-metal friction elements showing microstructure of bond between friction material and steel back. Nonmetallics in a matrix of bronze characterizes the appearance of the sintered-metal material. The layer of electroplated copper is comparatively thick, and its bond to the steel back has high strength



sintered iron on a steel back, riveted to the face of the cast-iron plate, *Fig.* 6. This expedient also controls the warping which often results from the heat effects of friction developed directly on the face of the cast plate.

For maximum friction, of course, both mating surfaces may be faced with metallic friction material. This practice has been suggested for heavy-duty clutches where high uniform friction is desired. As to the order of friction level of the various material combinations, sintered metal against steel is probably next best, followed by sintered metal against cast iron. Friction of sintered metal against chromium plate is the lowest.

Material Operating Characteristics: While friction and wear are of chief concern in the operation of friction surfaces, other important problems include scoring, squealing, glazing and metal deposit. Friction materials must be compounded and engineered so that these difficulties, to which they are so subject, do not develop in use. Failure to choose abrasive particles in the right size, kind or amount may cause a friction material to score the mating surface severely. This abrasive action is generally distributed over the surface, but it may also be localized in rather deep grooves which tend to grow larger, once they have started, rather than to smooth out. The tendency toward scoring is accentuated where the energy converted in a friction device is large. Once score marks have been put into a drum by the friction material, a reverse action can occur in which the lining may be adversely affected by the drum.

Another mutual surface effect is noise, or squeal, which may have its origin in either the lining or the drum, or both. Although linings must be properly compounded to prevent noisy operation, certain drums seem to squeal regardless of the lining applied, and it would appear that no change in the composition would provide a remedy. However, proper changes in the mass or shape of the drum may reduce the operating noise.

When metallic friction surfaces are operated under dry conditions, the appearance and composition of the surfaces undergo certain changes which are loosely described as glaze or film formation. These terms, however, may imply either a desirable or undesirable condition, depending on the extent of change in friction characteristics and wear rate of the mating surfaces. As a general rule, though, some sort of film is desirable.

A condition which has a reverse effect to scoring is that of friction metal deposit on the opposing face. There should be a fine balance between abrasive action of the material on the drum and the deposit of material from the lining. If a choice were to be made between deposit and abrasive action, the latter would be preferable. The compromise material would, therefore, keep the drum clean, even at the expense of a slightly abrasive action.

Metal deposit is promoted by gross welding of the material to the drum in large areas, after which more material of the lining is transferred to the metal already deposited. Mutual scoring is another undesirable effect of this action. In general the material condition which causes drum deposit is marked by friction instability.

Film Formation: While allusion was made to glaze formation previously, it is a subject of such magnitude that it should be given special attention in the study of metallic friction materials. Films may be divided into at least two classifications, depending on the manner of formation.

The first type of film is that formed by the drawing out of the matrix material along the friction surface in the direction of motion of the drum. This film formation is more apparent in the middle of the lining. As the action is continued, the ma-

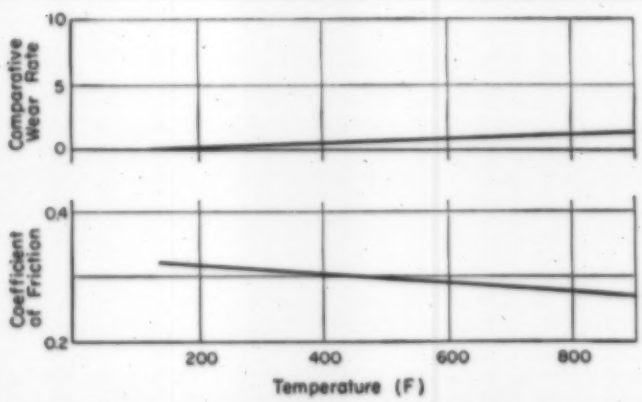


Fig. 5—Above—Effect of temperature on coefficient of friction and wear rate of sintered-metal friction materials

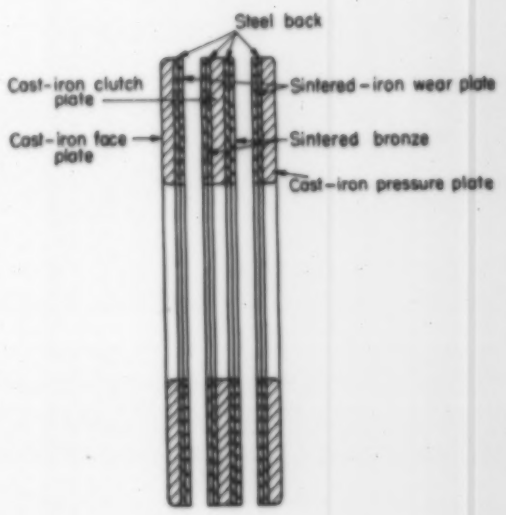


Fig. 6—Right—Construction of demountable wear plate for tractor clutches

terial tends to work harden and anneal, contributing to the formation of continuous film.

Another type of film formed on the surface of the friction material is the oxide of the friction element or drum material. The mechanism by which these films form is somewhat obscure and it is not possible to explain why one film will form, or to predict when another will appear.

Although films form on the surfaces naturally, and not as a result of material design or application, it is nevertheless possible to include in the formulation of the material certain ingredients which promote the formation of desirable films for certain purposes. The necessity for film formers such as solid lubricants arises out of the increasing propensity of friction materials to weld to the mating surface as operating temperatures rise. Thus, the formulating expert resorts to the use of sulphides, such as molybdenum disulphide. Boron nitride is also reputed to be such a solid lubricant. Graphite certainly operates in this manner under probably all temperature conditions, but may require reinforcement at high temperatures in some but not all types of composition.

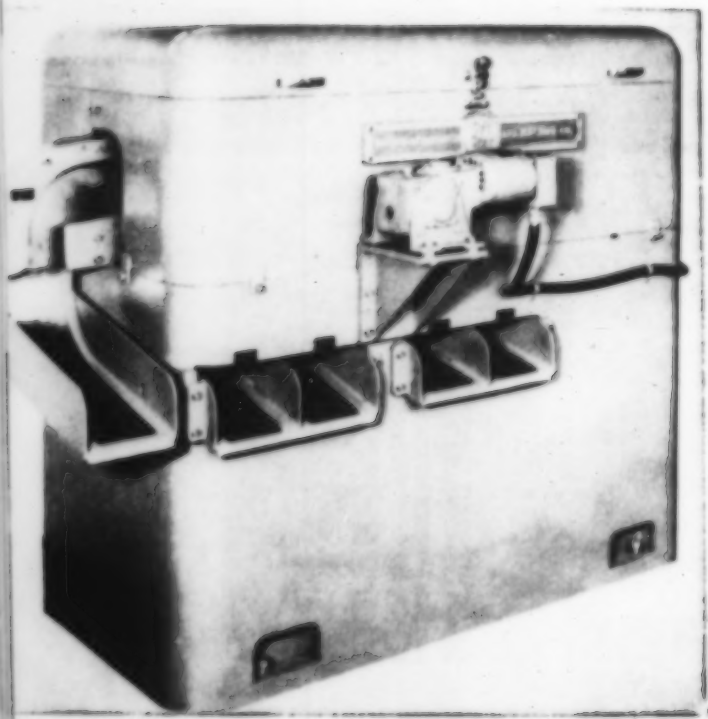
While the foregoing films are very likely to form during a dry application of friction materials, they are not as likely to form during applications which take place in an oil-sprayed or wet environment. It is also true that films generally do not form in clutches to the same extent as in brakes. Moreover, they do not appear to be so prevalent in low-energy brakes as they are in high-energy brakes. Some brake manufacturers consider it advantageous to have a glossy film develop on the surface to stabilize brake action.

From the previous discussion it would appear that it is desirable to have practically no film in a dry clutch, that little or no film will develop in a good wet clutch, and that it is good practice to have a film of the matrix material form on brake surfaces. Film formation is usually accompanied by a slight drop in the friction level and an appreciable drop in the wear rate. The latter, at least, is a desirable situation.

In the composition and formulation of sintered-metal materials, it is well to know what can be done to control the development of such films. Nonmetallic materials appear to have the property of breaking up the continuity of the metallic constituents. Abrasive material, such as silica and graphite, both of which are usually added to the composition, serve in this capacity. While lead is also added to almost all metallic materials, its function is still rather obscure, and whether it contributes to or retards the formation of films is not known.

Contemporary Design

Automatic Gear Checker



A NEW automatic motorized precision gear checker inspects gears by electronic indicators and comparison with a master gear for incomplete stroke, oversized and undersized teeth, and thick or thin teeth. Gears that do not meet inspection requirements for these dimensions are directed into selected chutes which sort out oversized, undersized, thick-tooth and thin-tooth gears.

Gears are loaded by hand and fed through the various inspection stages in the checker automatically. The gears first pass through a set of master gears where they are immediately rejected for incomplete tooth length if they will not roll through. Next the gears are checked for thick or thin teeth and finally for size. Automatic interlocks prevent the feeding of a gear through the checker until the previous gear has cleared the unit. Indicator lights on the machine tell the operator the reason for the rejection of any individual part. Producer of the checker is National Broach and Machine Co.

Fig. 1—Electronic vibration analysis of a rotary surface grinder. Displacement and frequency of vibration in machine parts are detected by hand-held seismic pickup with filtering probe and transmitted to the vibration analyzer, at left, which registers the information on the two panel meters

Electronic Vibration Analysis

By James E. Rhodes

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A RECENTLY developed concept, electronic vibration analysis offers a new approach to dynamic balancing of rotating machine assemblies. Unlike conventional balancing methods, this new technique does not require removal of individual parts or subassemblies from the complete machine assembly for separate analysis and balancing. Sources of unbalance are traced directly with parts operating in their natural working environment.

Basic System: The portable analyzer developed by International Research and Development Corp. consists of a hand-held seismic pickup with filtering probe, a stroboscopic light and a lightweight cabinet containing electronic circuits which transmit vibration information gathered by the pickup to panel meters showing displacement and frequency. In operation, the pickup probe is held against the housing or mounting of a suspected part, *Fig.* 1. Vibrations with displacements as small as 0.000001-inch are detected by the pickup; maximum standard frequency range is from 500 to 160,000 vibrations per minute.

The stroboscopic light is fired by the current generated by the pickup and thus flashes at the frequency of vibration and the speed of the moving part. It provides a "window" to balancing operations by showing the phase or location of unbalance in a rotating part.

Application Example: A typical example of the possibilities of the new technique is furnished by an application in the manufacture of a line of precision grinders at the Arter Grinding Machine Co. Balance tolerances on components and finished assemblies for several different types of grinder units are checked by a vibration analyzer of the type discussed previously. Although different in purpose, all of the grinder units involve close balance tolerances, high operating speeds, complex rotating assemblies and precision standards of performance.

To standardize inspection procedures, a series

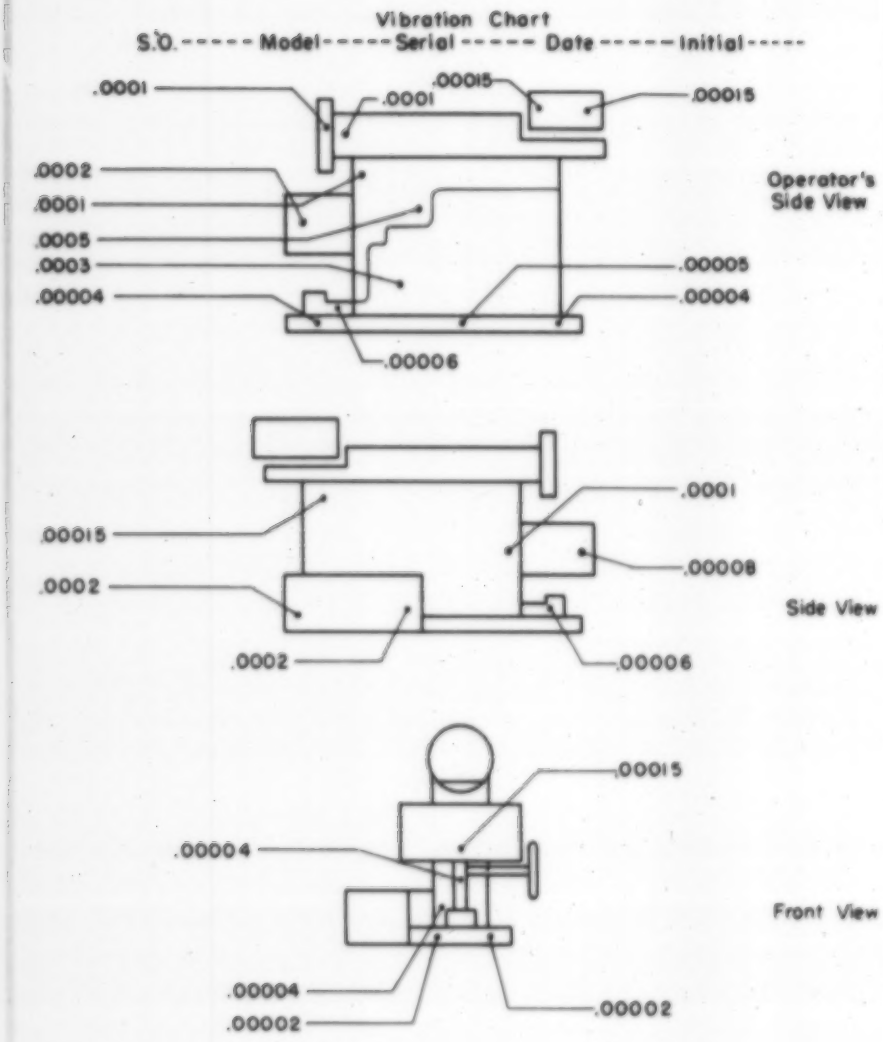

Fig. 2—Chart of maximum balance tolerances for a precision grinder. Tolerance values are expressed in terms of actual displacement, as measured by the vibration analyzer, at key points on the machine

of tight balance tolerances has been established in chart form, *Fig.* 2, for each key rotating component of each machine in the line. Inspectors, using a vibration analyzer, check each key point for vibration and compare it to the allowed value. The chart then becomes a part of the permanent record of the machine for future reference.

From experience gained with the new technique, the following concepts have been established in this particular application:

1. Standard-balance electrical motors can be purchased and balanced to meet specific assembly requirements. This operation is performed before assembly on a machine unit. Assembled units can then be checked.

2. Erected machines can be checked thoroughly on the test floor to compare readings with vibration chart values which have been set up as the overall standard required to produce top quality grinding performance.

3. The grinding wheel and collet assembly can be balanced on the machine. This practice eliminates the labor of removing and transferring the assembly to the balancing stand. Dynamic balancing on the machine is much more accurate than static balancing on a stand.

4. All rotating parts in the drives to the work chuck and the grinding wheel are prebalanced on a balancing machine before assembly. If any unbalance occurs in the final assembly, the part causing the trouble can be readily located with the vibration analyzer.

"If the day arrives when a majority of the people have an understanding of engineering principles, and when most engineers have a better understanding of people, then we will have an era of great promise."—JOHN C. SHARP, *president, Hotpoint Co.*

"The engineer who designs any part of the instrument must choose the best way to make it, not necessarily the easiest or the cheapest. It is poor economy to cut corners in dependability in a $20,000 instrument, and have it fail to function when needed, just to save $10 in the design of it."—HENRY MCKENNEY, *chief engineer, Ford Instrument Co.*

Method of finite differences provides simple but flexible arithmetical techniques for

CAM DESIGN

By Ray C. Johnson
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GENERAL purpose of a cam is to move a follower body from one position to another during a given angle of cam rotation. The type of motion which the follower body undergoes may be prescribed, or it may be left for the designer to choose the most desirable type of motion. In either case, it is often desirable to know how the velocity and acceleration of the follower body vary during the motion, especially in high-speed machinery where inertia forces are important.

For instance, in high-speed machinery, magnitudes of acceleration should be kept as low as possible and, yet, abrupt changes in acceleration should be avoided. Also, if the follower body strikes another body during its motion, the impact velocity should be kept as low as possible to avoid excessive impact forces between the two bodies. Hence, a ready method is desirable for obtaining the velocity and acceleration variations of the follower body during its cam-imparted motion.

This article develops a practical method which accomplishes this objective. The method is also effective as a tool for developing cam profiles to satisfy required operating characteristics together with optimum dynamic characteristics where they are important.

Basic Theory: Suppose that the displacements of a body from a fixed reference position are known at the endpoints of equal, small-time intervals which are ΔT in magnitude. A plot of displacement versus time could then be made, *Fig.* 1. Suppose that it is desired to obtain the velocity of point 0, which incidentally might be any general

This finite-difference method of solving cam design problems is rapid, and yields results well within the accuracy limits of cam manufacture. The basic theory can be applied to the solution of three general problems which are often encountered:

1. **Determining velocities and accelerations for the follower body of a given cam**
2. **Predicting effect of machining tolerances on accelerations and velocities of the follower body**
3. **Developing a cam profile which satisfies the specified conditions of the problem and yet gives the most desirable dynamic characteristics to the motion of the follower body**

point. Velocity, being the derivative of displacement with respect to time, is merely the slope of the displacement versus time curve.

Hence, from *Fig.* 1, slope of displacement plot at point 0 is

$$\left(\frac{ds}{dT}\right)_0 = v_0 = \frac{s_2 - s_1}{2(\Delta T)} \quad \ldots\ldots (1)$$

Equation 1 thus gives the velocity of the body at point 0 in terms of the displacements of the adjacent points 1 and 2. Velocities can thus be calculated at each point if the displacement variation is known.

Next, suppose it is desired to calculate the acceleration of the body at point 0 of *Fig.* 1. Acceleration is the derivative of velocity with respect to time, or merely the slope of the velocity versus time curve. Consider points *A* and *B* to lie midway between points 1 and 0, and points 0 and 2, respectively, as shown in *Fig.* 1. The velocity at point *A* can accurately be represented as

$$\left(\frac{ds}{dT}\right)_A = v_A = \frac{s_0 - s_1}{\Delta T} \quad \ldots\ldots (2)$$

Likewise,

$$\left(\frac{ds}{dT}\right)_B = v_B = \frac{s_2 - s_0}{\Delta T} \quad \ldots\ldots (3)$$

Hence, the velocity variation in the neighborhood of point 0, *Fig.* 2, is known. Calculating the slope of the velocity plot at point 0 gives the acceleration of the body at that point:

$$\left(\frac{d^2s}{dT^2}\right)_0 = \frac{v_B - v_A}{\Delta T} = \frac{\dfrac{s_2 - s_1}{\Delta T} - \dfrac{s_0 - s_1}{\Delta T}}{\Delta T}$$

or,

$$a_0 = \frac{s_1 + s_2 - 2s_0}{(\Delta T)^2} \quad \ldots\ldots (4)$$

The basic theory which has been developed so far will now be applied to the general cam design problem. During the interval ΔT the cam rotates through the angle $\Delta\theta$ at the constant angular velocity ω. Therefore, from elementary mechanics, $\Delta\theta = \omega(\Delta T)(360/60)$. The numerical factor enters in order to have the correct relationship of units. Hence, $\Delta T = (\Delta\theta)/6\omega$. Substituting this relationship into Equations, 1 and 4 gives

$$v_0 = 3\,\frac{\omega}{\Delta\theta}\,(s_2 - s_1) \quad \ldots\ldots (5)$$

$$a_0 = 36\left(\frac{\omega}{\Delta\theta}\right)^2 (s_1 + s_2 - 2s_0) \quad \ldots\ldots (6)$$

Study of the mathematical method used in deriving these equations shows that they are approximations. However, the accuracy is found to be very high if the cam angle interval, $\Delta\theta$, is not unreasonably large and if the follower body displacement variation is smooth.

In Equation 5, the term $(s_1 - s_2)$ will be referred to as the velocity factor. In Equation 6 the term $(s_1 + s_2 - 2\,s_0)$ will be referred to as the acceleration factor. In both of these equations, s_0 is the displacement of the follower body at the point in question while s_1 is the displacement at the adjacent previous point and s_2 is the displacement at the adjacent following point.

With Equations 5 and 6, the velocity and acceleration of the follower body at any general point can be calculated if the cam-imparted follower body displacements are known at equally spaced

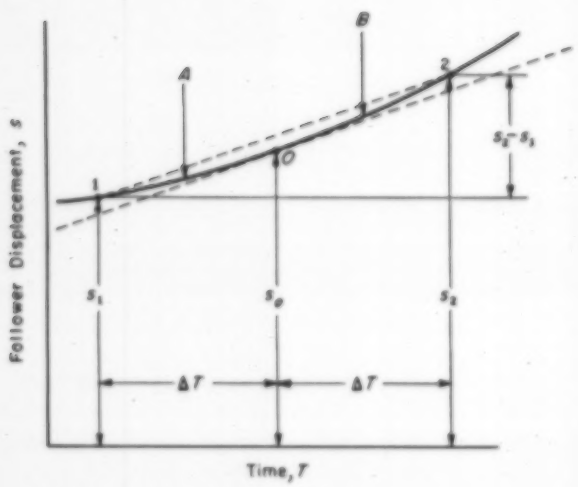


Fig. 1—Plot of follower displacement versus time, showing three adjacent points: 1, 0 and 2. Point 0 is the one under consideration

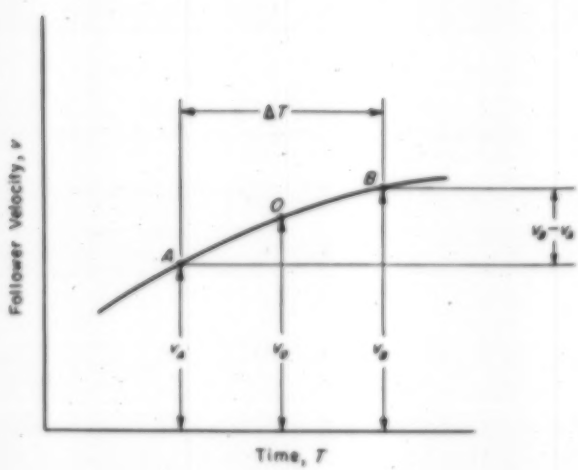


Fig. 2—Plot of follower velocity versus time, showing two points, *A* and *B*, midway between points 1 and 0, and 0 and 2, of *Fig.* 1

points of cam rotation. This theory will now be applied and illustrated for three general cam design problems.

Primary Analysis of a Cam: Suppose that it is desired to make a dynamic analysis of the follower body primary motion for a portion of the rotation of a cam which has already been made, or one whose motion follows a definite law. The secondary motion component which is caused by machining or measuring tolerances will be covered in the next section. It will be assumed that the displacements of the follower body are known at equally spaced intervals of cam rotation. Equations 5 and 6 may be applied directly to the solution, as is illustrated in *Example* 1.

Effect of Machining Tolerances: From a practical standpoint, it is well known that cams can not be made as precisely as desired because of machining tolerances. Hence, the follower body will fluctuate somewhat from its desired displacement variation, as illustrated by *Fig.* 3. The actual displacement of the follower body will therefore consist of the primary displacement which is desired and a secondary component which is caused by machining tolerances. This secondary displacement component will, in turn, cause secondary components of acceleration and velocity superposed on the primary acceleration and velocity.

If the master cam is machined from displacement points which are given every $\Delta\theta$ degrees, then it is reasonable to assume that the tolerance-caused deviation of the actual follower body displacement curve from the desired curve will be cyclical in nature, *Fig.* 3. Great care is also generally taken in avoiding steps or abrupt changes in the cam profile at any point. Hence, it is reasonable to assume that the tolerance-caused displacement deviation will be fairly smooth. Therefore, it is reasonable to apply Equations 5 and 6 to the problem which will now be considered.

The worst possible condition, from a dynamic standpoint, exists at the three adjacent points which are denoted by x, y and z in *Fig.* 3. At point y the secondary component of acceleration is a maximum, and Equation 6 may be applied:

$$a_s = 36\left(\frac{\omega}{\Delta\theta}\right)^2 [+t + t - 2(-t)]$$

$$= \pm 144\left(\frac{\omega}{\Delta\theta}\right)^2 t \qquad (7)$$

It should be pointed out that Equation 6 is not *precise* when applied to the secondary fluctuations of *Fig.* 3. The cam angle interval $\Delta\theta$ is, relatively speaking, far too large for accuracy when considering the secondary fluctuations. The resulting inaccuracy would be such that the actual maximum deviation of the follower body acceleration from the primary variation would be larger than the calculated value. However, the extreme displacement deviation illustrated by points x, y and z of *Fig.* 3 would be a rather rare condition. Hence, the actual maximum acceleration deviation in many cases would be smaller than the calculated value under the assumed rare condition. The cushioning effect introduced by the elastic deformations at the follower and cam contact surface regions would have the same effect.

Therefore, Equation 7 gives the average maximum deviation of the follower body acceleration from the primary value. However, Equation 7 is as accurate as is possible in predicting the effect of cam machining tolerances on the follower body acceleration, since the cam profile curvature between machine setting points is not accurately controlled. Therefore, Equation 7 gives as good an indication as is possible of how the acceleration will fluctuate from the primary variation due to machining tolerances.

Equation 7 indicates that a_s approaches infinity

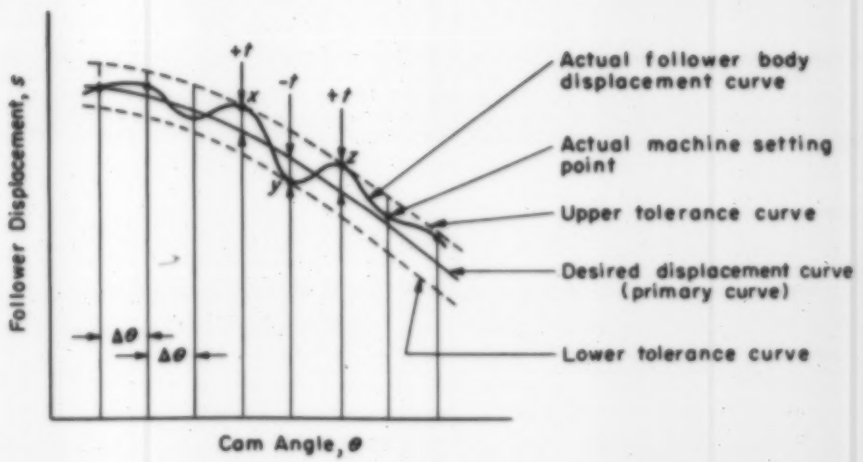


Fig. 3—Follower displacement curves showing how secondary displacement curve resulting from tolerances is superposed on primary displacement curve

Nomenclature

ω = Constant angular velocity of the cam; rpm

$\Delta\theta$ = Interval of cam rotation for which the follower body displacement points are given; degrees

ΔT = Time interval corresponding to $\Delta\theta$; seconds

s = Displacement of the follower body from a fixed reference position; inches, if the follower body undergoes linear motion, or radians if the follower body undergoes angular motion. Subscript 0 denotes the particular point in question whereas subscripts 1 and 2 denote the two points adjacent to that point.

v_0 = Primary velocity of the follower body at a point in question; inches per sec for linear follower motion, or radians per sec for angular motion

a_0 = Primary acceleration of the follower body at a point in question; inches per sec^2 for linear follower motion, or radians per sec^2 for angular motion

t = Maximum deviation of the follower body displacement from the desired value due to machining or measuring tolerances; units same as for s

v_t = Average *maximum deviation* of the follower body velocity from the primary value due to machining or measuring tolerances (termed secondary velocity); units same as for v_0

a_t = Average *maximum deviation* of the follower body acceleration from the primary value due to machining or measuring tolerances (termed secondary acceleration); units same as for a_0

as $\Delta\theta$ approaches zero. This would be true for a cam having a knife-edge follower. However, it is not true for the commonly encountered roller follower or flat-face follower type of cams. It can be proved mathematically that for these cam types a limiting value of $\Delta\theta$ exists for which a_t remains constant in magnitude as $\Delta\theta$ is decreased below this limiting value. This limiting value of $\Delta\theta$ depends on the machining tolerances, cam pressure angle, radius of curvature of both the cam surface and the follower at the point of contact, and other geometric relations of the particular cam. Assuming that machining tolerances will be equal to or less than $\pm$0.0005-inch, the author has found that this limiting value of $\Delta\theta$ is generally less than ½-degree for roller-follower type of cams, and it is generally less than 1 degree for flat-face follower type of cams. Equation 7 is valid for values of $\Delta\theta$ equal to or larger than this limiting value.

This limitation for Equation 7 is not a practical limitation in high-speed machinery, since a_t will generally be far more excessive than is necessary when the limiting value of $\Delta\theta$ is used for the cam angle interval. In other words, the optimum choice of $\Delta\theta$, as is explained later, is generally quite a bit larger than the value which makes Equation 7 invalid.

In a like manner, Equation 5 may be used in predicting the average maximum deviation of the follower body velocity from the desired primary value. The worst possible condition for this problem exists at the midpoint between points y and z or points x and y of *Fig.* 3. Hence, from Equation 5,

$$v_t = 3\left(\frac{\omega}{\frac{\Delta\theta}{2}}\right)\left[+t - (-t)\right]$$

$$= \pm\ 12\left(\frac{\omega}{\Delta\theta}\right)t \qquad (8)$$

In general, the comments concerning the precision of Equation 7 in actual use might also be made with respect to Equation 8. Again, however, the equation is as accurate as it can be for actual cams.

Equations 7 and 8 are applied to typical design in *Example* 2. From this example it is seen that the secondary velocity fluctuation is not nearly as great as the secondary acceleration fluctuation, due to machining tolerances. However, velocity fluctuations might be of importance for specific problems even though they are not high in magnitude. *Example* 2 illustrates the importance of cam smoothness in high-speed machinery.

Dynamically Satisfactory Cam Profile: In high-speed machinery it is especially important, because of dynamic forces, to keep accelerations of the follower body to as low a value as possible. Abrupt changes in acceleration should also be avoided. The effect of acceleration fluctuations of the follower body due to machining tolerances in making the cam should be kept as low as feasible. These objectives can be accomplished with a relatively rapid, systematic method for designing a cam, and the degree of accuracy is as high as practical.

The general cam design problem consists of satisfying certain specified conditions along with the foregoing dynamic consideration. The process of developing a cam for a given problem essentially consists of three steps.

Step 1: *Choosing the interval of cam rotation for calculating displacements.* In most cam design problems, the question often arises as to how small a cam angle interval, $\Delta\theta$, should be chosen for calculating the follower body displacements. One would most naturally think that the smaller the interval the better, but this is not necessarily true. Exorbitant fluctuations in acceleration of the follower body due to machining tolerances of the cam can exist if the displacement points of the follower body are given too close together. Then the actual cam profile might fluctuate from the theoretical profile at too great a rate.

This possibility is quite apparent from Equation 7, which shows that for a given machining toler-

ance and speed of cam rotation, the average maximum deviation of the follower body acceleration from its primary value varies *inversely* as the square of the cam angle interval. Hence, choosing too small a value for the cam angle interval, $\Delta\theta$, might very well result in too much of a "washboard" effect on the cam surface and exorbitant fluctuations of the follower body acceleration from its primary variation.

However, choosing too large a value for the cam angle interval may also invite trouble, since then Equation 6 might not be accurate to the desired degree. From this discussion, it is apparent that an optimum cam angle interval exists, and $\Delta\theta$ should be chosen so as to fall fairly close to that value.

Rearranging Equation 7 gives the following equation which should be used in determining the appropriate value for the cam angle interval, $\Delta\theta$:

$$\Delta\theta = 12\,\omega\sqrt{\frac{t}{a_t}} \qquad (9)$$

From experience, it has been found that Equation 9 gives a good approximation to the optimum cam angle interval, $\Delta\theta$, if a_t in that equation is chosen as approximately equal to one-half of the maximum acceleration which is finally expected from the primary motion of the follower body. If, however, the designer can not initially approximate the final maximum acceleration for the follower body final primary motion, then he should use as large a value for a_t in Equation 9 as is considered to be tolerable.

If the cam angle interval, $\Delta\theta$, obtained by either of the suggested methods seems unreasonably large, then the designer should either (1) consider decreasing his specified tolerance value to obtain greater machining accuracy, if such a possibility exists, or (2) consider accepting larger acceleration fluctuations due to machining tolerances. Both of these factors allow a more satisfactory choice for $\Delta\theta$ when this particular difficulty is encountered.

Step 2: *Choosing the initial follower body displacements*: Once a reasonable value for the cam angle interval, $\Delta\theta$, has been chosen with Equation 9, a first approximation to the follower body displacements must be made. It is wise to make as close a first approximation as possible, since then the displacements will not have to be adjusted so much in developing a dynamically satisfactory profile. Hence, it is suggested that the initial follower body displacements be obtained by normal design procedures using the well-known constant acceleration solution to the particular problem at hand. Constant acceleration is suggested since it always gives the minimum value for the maximum primary acceleration. The characteristic abrupt changes in acceleration for that type of solution can then be easily smoothed out by the displacement adjustment procedure which is outlined later in this article.

At this point, however, it should be emphasized that the initial follower body displacements can be obtained in any way whatsoever. Merely plotting on graph paper the specified follower body displacements versus cam angle position and using a French curve to obtain a smooth primary follower body displacement variation in the intermediate profile development regions is perfectly satisfactory. In other words, the method for obtaining initial follower body displacements in the profile development region is not important, since they can be adjusted to give equally good, dynamically satisfactory characteristics in the next step.

Step 3: *A systematic method for adjusting initial follower body displacements in order to obtain desirable dynamic characteristics:* Assume that a smooth initial follower body displacement variation has now been obtained in the cam profile development region. The acceleration factor, $(s_1 + s_2 - 2s_0)$, can then be calculated at each point, and it indicates how the primary acceleration initially varies. It is merely a matter then of *adjusting* the *initial displacements* to obtain a smoothly varying acceleration factor. The follower body displacement adjustment process essentially consists of two parts, which will be denoted as

Cam Manufacturing Techniques

Design methods presented here are uniquely suited to the conventional process for producing a master cam. The finite-difference method of computing profiles has its direct counterpart in the "step" milling of the final cam.

The degree of accuracy needed in high-speed machinery generally requires that a master cam be made at least four or five times actual size. The master cam is milled step by step every $\Delta\theta$ degrees—the increments of cam rotation for which the follower displacements have been calculated. Aided by a marking compound, a skilled machinist can then file the scalloped contour down to a smooth profile joining the machine setting points. With a pantograph device or other copying mechanism, final cams of proper size can be finish ground from the master cam.

Step 3A and Step 3B.

Step 3A consists of adjusting follower body displacements so that the acceleration factors have no local fluctuation similar to the one illustrated in *Example* 3. In that example, the initial acceleration factor varies, in the region shown, from a low to a high to a medium value.

These types of local fluctuations can readily be smoothed by adjusting the follower body displacements one at a time, and in the process correcting the acceleration factors. Necessary acceleration factor corrections are apparent for any displacement adjustment by the definition of acceleration factor itself as $(s_1 + s_2 - 2s_0)$.

The follower body displacements are successively adjusted using the principle of always adjusting the displacement of the point whose acceleration factor deviates most from a smooth curve. For each follower body displacement adjustment made, the proper acceleration factors are corrected. Since the acceleration factor of an adjusted displacement point changes twice as much as the acceleration factors of the two adjacent points, the adjustment method is inherently convergent to the condition of no local fluctuations for the acceleration factors. These individual types of corrections as illustrated in *Example* 3 should be made whenever they seem necessary in the development procedure.

From *Example* 3, it is obvious that adjustment of the displacement of any point results in a correction of the acceleration factors for three points. For the point whose displacement has been adjusted, the change in the acceleration factor equals -2 times the displacement adjustment. For each of the two points adjacent to the point whose displacement has been adjusted the acceleration factor changes by $+1$ times the displacement adjustment. Great care should be exercised in observing signs of the displacement adjustment in order to make the proper corrections of the acceleration factors.

The second part of the follower body displacement adjustment process, Step 3B, will now be considered. This part consists of traversing the points in a sequential manner, adjusting the displacements by considering the effect each adjustment has on the acceleration factors. If the displacement adjustments are made by following a sequential traverse, the variation of the accelera-

Example 1—Primary Analysis of a Cam

Suppose that the follower displacements are given for 2-degree intervals in the interval from 230 degrees to 240 degrees of the cam. Assume that the velocity and acceleration variations in the interval from 232 degrees to 238 degrees are to be determined. The given displacements together with the results of the analysis are shown in the accompanying table.

For this problem, $\Delta\theta = 2$ degrees. Now, specifically consider the 236-degree cam position point of the table. For that point, the following values exist: $s_0 = 3.409$ inches, $s_1 = 3.406$ inches, and $s_2 = 3.411$ inches. Hence, Equation 5 gives

$$v_0 = 3\omega\left(\frac{3.411 - 3.406}{2}\right) = 0.0075\,\omega$$

Equation 6 gives

$$a_0 = 36\,\omega^2\left[\frac{3.406 + 3.411 - 2(3.409)}{(2)^2}\right]$$

$$= -0.009\,\omega^2$$

Thus, if $\omega = 500$ rpm,

$v_0 = .0075\ (500) = 3.75$ inches per sec

$a_0 = -\ .009\ (500)^2 = -\ 2250$ inches per sec^2

The negative sign merely indicates that the velocity is decreasing at that point.

Cam Position θ (degrees)	Fol. Displ. s_0 (inches)	s_1	s_2	v_0 (from Eq.5)	a_0 (from Eq.6)
230	3.401				
232	3.403	3.401	3.406	$+.0075\omega$	$+.009\omega^2$
234	3.406	3.403	3.409	$+.009\omega$	0
236	3.409	3.406	3.411	$+.0075\omega$	$-.009\omega^2$
238	3.411	3.409	3.412	$+.0045\omega$	$-.009\omega^2$
240	3.412				

Example 2—Effect of Machining Tolerances

Suppose that a cam can be machined to a degree of accuracy which guarantees a maximum variation of the follower body displacement of $\pm$ 0.0005-inch from the theoretically correct displacement. Also, suppose that the interval of cam rotation for machine settings is 5 degrees. Equation 7 then indicates that the average maximum deviation of the follower body acceleration from the primary acceleration would be

$$a_t = \pm\ 144\left(\frac{\omega}{5}\right)^2 (0.0005) = \pm\ 0.00288\,\omega^2$$

Hence, if $\omega = 1000$ rpm, $a_t = \pm 2880$ inches per sec^2. Such an acceleration fluctuation might very well be quite appreciable.

From Equation 8, the average maximum deviation of the follower body velocity from the primary velocity would be

$$v_t = \pm\ 12\left(\frac{\omega}{5}\right)(0.0005) = \pm\ 0.0012\,\omega$$

Hence, if $\omega = 1000$ rpm, $v_t = \pm\ 1.2$ inches per sec. Such a velocity fluctuation would most likely not be exorbitant.

tion factor can readily be made flatter, smoother, or to have any other general characteristic desired.

Generally, several traverses are necessary in order to obtain the desired acceleration factor characteristics. In any particular traverse, the designer should not only make displacement adjustments to obtain desired acceleration factors in the locality under consideration, but also watch the displacement adjustment trend to see that it does not run away from initial displacements too far. Otherwise a large acceleration factor will result at the end of the traverse, and thus many more traverses will be necessary for a satisfactory development.

The sequence of traverse and the amount of adjustment to be made for the follower body displacements at each point depends on the arithmetic ingenuity of the designer, and the number of wise choices made decidedly improves with a little practice.

For the particular design given here (*Example* 4), Step 3A of the adjustment process was unnecessary, since the initial follower body displacement values were originally calculated very accurately mathematically by the well-known constant acceleration solution to the problem. Thus, local fluctuation did not exist for the initial acceleration factors. However, Step 3A would be very important if the initial follower body displacements were roughly approximated by the graphical plot method suggested under Step 2. However, Step 3B of the adjustment process makes it possible to obtain any feasible general acceleration factor characteristic which is desired, once Step 3A has been finished, no matter how the initial follower body displacement values were calculated. The traversing method of Step 3B is illustrated in *Example* 4.

In both Step 3A and 3B of the follower body displacement adjustment procedure, there exist several possible pitfalls which might be avoided by adherence to the following suggestions:

1. Do not adjust displacements which are specified as given values in the problem.
2. Calculate acceleration factors at all cam interval end points. Otherwise, you cannot tell whether or not the acceleration factor varies smoothly from a given or specified point to an adjacent point lying in the profile development region.
3. Avoid peaks in the acceleration factor variation, even though the variation is smooth. A lower maximum primary follower body acceleration will result if the acceleration factor variation is smooth and fairly flat. For the same reason, in any profile development region, an attempt should be made to keep fairly equal the largest magnitudes of both positive and negative acceleration factors.
4. Be careful in adjusting follower body displacements for a satisfactory acceleration factor variation where velocity is important. For problems where velocity is important, the velocity factor $(s_2 - s_1)$ should be considered. Adjusting the follower body displacement of a given point affects the velocity factors of the two adjacent points.

After Steps 3A and 3B have been completed, it is suggested that the acceleration factors be recalculated using the *adjusted* follower body displacements in Equation 6. The acceleration factors so calculated will indicate whether or not any arithmetic errors were made in the adjustment process since they should be the same as the corrected acceleration factors left from the adjustment process. Generally a very small amount of additional adjustment will then be necessary if errors have been made.

One additional technique should be mentioned,

Example 3—Initial Adjustment of Local Acceleration Fluctuations

Suppose that the initial follower body displacements for a specific problem indicate by the computed acceleration factors that a local fluctuation exists for the region shown in the accompanying table. Data for the 60-degree point and its two adjacent points are extracted from the problem and are given in the table.

Suppose the acceleration factor of the 60-degree point is to be reduced in an effort to get rid of the local fluctuation. The method used in this process is shown below in the table. If the displacement of this point is adjusted by $+20$, its acceleration factor changes by $-2(+20)$ or -40. Hence, its corrected acceleration factor becomes $+100 - 40 = +60$. The $+100$ is thus crossed out and $+60$ is substituted for the acceleration factor of this point. However, increasing the displacement of the 60-degree point by $+20$ also changes the acceleration factor of the 58-degree point by an amount of $+20$, since the 60-degree point is the s_2 point for the 58-degree point. Also, the acceleration factor for the 62-degree point changes by $+20$, since the 60-degree point is the s_1 point for the 62-degree point. Notice that the displacements of the 58 and 62-degree points have remained unchanged from their original values, whereas the displacement of the 60-degree point is now actually $(8100 + 20) \times 10^{-4}$ inches.

Cam Position θ (degrees)	Fol. Displ. (inches x 10^{-4})	Displ. Adj. (inches x 10^{-4})	Accel. Factor $(s_1 + s_2 - 2s_0)$
58	8000		~~+20~~ +40
60	8100	+20	~~+100~~ +60
62	8300		~~+80~~ +80

Example 4—A Typical Cam Design Problem

Suppose at $s = 1.000$ inch, the follower body has a constant velocity of + 10 inches per sec, upward. The speed of cam rotation is to be 1200 rpm. Suppose that after the cam rotates through 40 degrees the follower body must be at a position of $s = 0.9000$-inches and have a velocity of + 20 inches per sec, upward. The problem is to develop a cam profile which will accomplish these requirements and have a smoothly varying, relatively low magnitude acceleration motion. Assume that the cam profile can be made such that each setting given can be held within ± 0.0003-inch, with a smooth variation between settings.

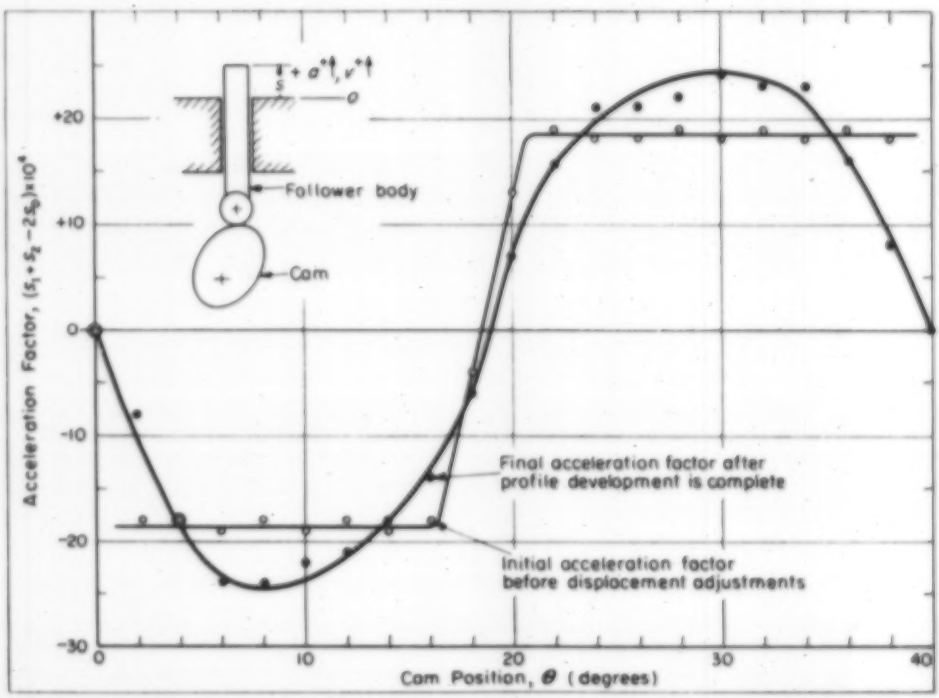
From the well-known constant-acceleration solution to the problem, a magnitude of 23,880 inches per sec^2 is mathematically calculated for the value of the constant acceleration required. It can be assumed that the primary acceleration will finally be about 20 per cent higher than this in places, due to the fact that low acceleration must be sacrificed somewhat for smoothness. Therefore, it is reasonable to assume that the maximum primary acceleration will finally be approximately 29,000 inches per sec^2. Hence, the value of a_1 to use in Equation 9 would be approximately one half of this value, or 14,500 inches per sec^2. Using this value for a_1, 0.0003-inch for t, and 1200 rpm for ω, gives a cam angle interval of 2.07 degrees by means of Equation 9. Therefore, for this problem, the cam angle interval, $\Delta\theta$, will be 2 degrees.

Using Equation 7 shows that the average maximum deviation of the follower body acceleration from the primary value, due to machining tolerances, will be ± 15,600 inches per sec^2. The difference is due to the exact value of 2 degrees being used for the cam angle interval instead of 2.07 degrees. Since fluctuations of this magnitude certainly are appreciable, assume that this is quite close to the maximum which the designer feels is allowable.

If the designer had erroneously assumed that the cam angle interval, $\Delta\theta$, should be made equal to 1 degree under the false assumption that it would necessarily give a smoother cam, Equation 7 shows that a_1 would be equal to ± 62,400 inches per sec^2, which would certainly be exorbitant.

The follower body displacements are then calculated at 2-degree intervals with the constant-acceleration solution to the problem. The initial follower body displacements thereby obtained are shown in the second column of the accompanying table. The initial acceleration factors are next calculated from the initial displacements, and they also appear in the table. These acceleration factors, plotted in the accompanying graph, show the abrupt changes in acceleration existing for constant-acceleration solutions. From the graph, the average magnitude of the acceleration factor is found to be 18.5×10^{-4}. Hence, use of Equation 6 shows that the maximum acceleration is $36\ (1200/2)^2\ (18.5)\ (10)^{-4} = 24{,}000$ inches per sec^2. This value is obtained from the initial follower body displacements with Equation 6, while the value of 23,880 inches per sec^2 was initially obtained by the mathematical constant-acceleration solution to the problem. The difference is approximately 0.5 per cent. Hence, a high degree of accuracy can be expected of Equation 6.

Steps 1 and 2 of the profile development procedure have now been covered. Next the initial follower body displacements must be adjusted in order to obtain a smoothly varying acceleration factor. Step 3A of the adjusting process is not necessary, since the mathematical solution leaves



no local fluctuations in the acceleration factors.

Step 3B of the adjustment procedure is necessary, however. Three traverses are made, as shown by the two sets of columns numbered 1, 2, and 3 in the accompanying table and two displacement points are adjusted as a final touch (pair of number 4 columns). The first traverse starts at the 4-degree point; follower body displacement is adjusted by an amount which changes the acceleration factor of the 2-degree point to a more desirable value. For this follower body displacement adjustment, the acceleration factors of the 2, 4 and 6-degree points are corrected to the values shown by the first figure to the right of each of those three initial acceleration factors. The 6-degree follower body displacement is next adjusted to give a more suitable value to the acceleration factor of the 4-degree point, and the acceleration factors for the 4, 6 and 8-degree points are then corrected in compliance with the displacement adjustment just made for the 6-degree point. Displacement adjustments together with their acceleration factor corrections are then made in order down to the 36-degree point, and all steps in this first traverse are shown in the two number 1 columns.

After this first traverse, the last acceleration factor shown in column 1 on each line is left with no diagonal line through it and represents the acceleration factor variation at this point in the development. From the results of this first traverse it is noticed by visual inspection that not much improvement has been gained in acceleration factor smoothness near the middle and end of the traverse. Hence, the second traverse is started at the 36-degree point and is carried up to the 16-degree point. After this second traverse, it can be visually observed that the acceleration factors vary fairly smoothly at the ends but still are quite undesirable at the center. Hence, a final traverse, shown in the two number 3 columns is made, starting with the follower body displacement of the 14-degree point and continuing to the 28-degree point. Two undesirable local acceleration factor conditions are then noticed and corrected by local displacement adjustments as described in Example 3. This final step is shown in the number 4 columns.

The three traverses took the author a total time of approximately 30 minutes, working cautiously. Additional traverses could have been made, but the further refinement seemed unnecessary in view of the large acceleration fluctuations due to machining tolerances.

From the graph, the maximum value for the final acceleration factors is seen to be approximately 24 $\times$ 10^{-4} inches per sec^2. Hence, with Equation 6, it is found from that value that the actual maximum primary follower body acceleration is 31,200 inches per sec^2. The average maximum deviation of the follower body acceleration from the primary value, due to machining tolerances, was initially calculated to be 15,600 inches per sec^2. Incidentally, it is merely a coincidence that this value is exactly one-half that of the maximum primary acceleration of 31,200 obtained from the developed profile.

For any given point, the actual follower body displacement to be used in making the cam is the algebraic sum of the initial displacement plus any adjustments. Thus, the follower body displacement of the 22-degree point is seen from the table to be (9249 $-$ 2 $-$ 10 + 3) $\times$ 10^{-4} inches = 0.9240-inch.

Cam Position θ (degrees)	Initial Fol. Displacement (inches x 10^4)	Displ. Adjustments (inches x 10^4)				Init. Accel. Factors (x10^4)	Corrected Acceleration Factors (x 10^4)			
		1	2	3	4	$(s_1 + s_3 - 2s_2)$	1	2	3	4
0	10,000	*				0				
2	10,018	**				-18	-8			
4	10,018	+10				-18	-38 -18			
6	10,000	+20				-18	-18 -56 -24			
8	9 963	+25				-18	+2 -56 -28			-24
10	9908	+23			+1	-18	+8 -90 -20			-22
12	9 834	+20				-18	+8 -36 -18		-28	-21
14	9 742	+16		-3		-18	+4 -34 -18	-21	-18 -18	
16	9631	+13	-3	-3		-18	+2 -28 -18	-28 -18	-28 -18 -14	
18	9502	+10	-7	+2		-18	+8 -34 -18	-18 -18 -18	-28 -34 - 6	
20	9 369	+6	-10	+5		+18	+28 +14 +18	-18 +18 +18	+18 +8 + 7	
22	9249	-2	-10	+3		+18	+28 +28 +18	+8 +28 +18	+24 +18	
24	9 148	-10	-10	0		+18	+18 +36 +21	+18 +36 +20	+28 + 21	
26	9065	-15	-11	-2		+18	+8 +36 +28	+28 +28 +18	+28 + 21	
28	9000	-16	-15	-2		+18	+18 +36 +21	+18 +36 +20	+18 + 22	
30	8954	-15	-20			+18	+28 +36 +20	+8 +36 +28	+28	+24
32	8926	-12	-20		+1	+18	+18 +28 +20	+8 +36 +28		+23
34	8 917	- 8	-15			+18	+8 +28 +18	+12 +28 +28		+23
36	8926	- 4	- 6			+18	+14 +18	+28 +18		
38	8954	**				+18	+14	+8		
40	9000	*				0				

* These displacements are not adjusted since they are specified as given values in the problem.

** These displacements are not adjusted since the velocity of an adjacent point (0 or 40 degrees) is given as constant.

since its use often reduces the labor required to develop a dynamically desirable cam whenever the cam angle for the development region is large.

Step 1 of the profile development procedure is followed exactly as before. A desirable cam angle interval $\Delta\theta$ is thereby selected. However, since the cam angle for the development region is large, and since $\Delta\theta$ is always reasonably small, many displacement points will have to be calculated and subsequently adjusted. Hence, it is suggested that an initial development be made with a coarse cam angle interval. For instance, if $\Delta\theta$ represents the final cam angle interval as determined by Step 1, then the initial development might be made using an interval of $2\Delta\theta$ degrees. The initial development using this coarse interval is then carried out using Steps 2 and 3 as in *Example* 4. After this initial coarse development is complete, the stage is set for the final development.

The final development is carried out in the following manner. The displacement points from the initial development are recorded, and they represent fairly accurate approximations of the desired displacement values, every $2\Delta\theta$ degrees. The intermediate displacement values for this final development are approximated using straight-line interpolation. The result is a fairly good approximation of the desirable displacement points at the start of the final development. Acceleration factors are then calculated, and displacement adjustments are made using Step 3 as before. However, since fairly good approximations of the desirable displacement points are available at the start of the final development, a very small amount of labor has to be expended on the final development.

The same techniques can be carried still further. For instance, suppose the cam angle interval chosen under Step 1 is represented by $\Delta\theta$ degrees. The initial development might then be made using an interval of $8\Delta\theta$ degrees. The next development would then be made using an interval of $4\Delta\theta$ degrees, by using at the start of this development the displacement values from the initial development. The next development would then be made using an interval of $2\Delta\theta$ degrees, by using at the start of this development the displacement values from the previous development. The final development would then be made using an interval of $\Delta\theta$ degrees, by using at the start of this final development the displacement values from the previous development.

Jerk: In cam design, jerk is considered to be the time rate of change in acceleration—the derivative of acceleration with respect to time or the third derivative of displacement with respect to time. Avoidance of excessive jerk is just another way of stating avoidance of abrupt changes in acceleration. Hence, it is sometimes desirable to have an expression available for calculating jerk at a point. The following equation was derived in a manner similar to that used for deriving Equations 5 and 6:

$$\left(\frac{d^3s}{dt^3}\right)_0 = j_0 = 108\left(\frac{\omega}{\Delta\theta}\right)^3\left[(s_4 + 2s_1) - (s_3 + 2s_2)\right] \quad \ldots\ldots (10)$$

where j_0 denotes the jerk at any point in question. The subscripts refer to five adjacent points having the order 3, 1, 0, 2, and 4 in the direction of increasing cam angle θ, and as before, 0 is the particular point in question.

Since actual follower body acceleration will fluctuate considerably from the primary acceleration due to machining tolerances in practical problems, a visual smoothing of the acceleration factors in the manner of *Example* 4 is generally considered to be sufficient. Hence, Equation 10 at this time seems to hold little practical significance.

Conclusions: The method developed and presented in this article for the problem of cam design makes use of the theory of finite differences. This theory has been similarly applied successfully for many years in the field of stress analysis with a high degree of accuracy.* For example, the author has used the method extensively in stress analysis and results so obtained have checked very closely with results obtained photoelastically. The error is generally less than 2 per cent. The author has applied the theory to cam design problems also, and it has proven to be a powerful and effective practical tool.

As this article shows, the method is simple. A cam profile can be developed having any desired type of dynamic characteristics and the designer needs only to be thoroughly familiar with the arithmetic process of correcting acceleration factors for follower body displacement adjustments. Since the basic method is arithmetic in nature, it can be mastered in a short period of time. Countless hours can be saved in designing cams, and the results will generally be far more satisfactory from a dynamics viewpoint.

*S. Timoshenko and J. N. Goodier—*Theory of Elasticity*, McGraw-Hill Book Co. Inc., New York, 1951. Pages 461-462.

"Engineering, above all other professions, contributes toward the betterment of human life by providing practical application to progressive scientific knowledge—the means whereby the creative imagination of the scientist is put to practical use—and by devising mechanical processes expedites the requirements of everyday life. Thus, he who tills the soil to produce the food we eat must look to the engineer to devise the means of irrigation, of mass production and of wide distribution; he who weaves the yarn to produce the clothes we wear must look to the engineer to devise the mechanics whereby may be met the mass needs of our expanding population; and he who builds the homes in which we live must look to the engineer to provide essential aids to human labor."—DOUGLAS MACARTHUR

Analyzing
COLUMN STABILITY

under varying end-load conditions

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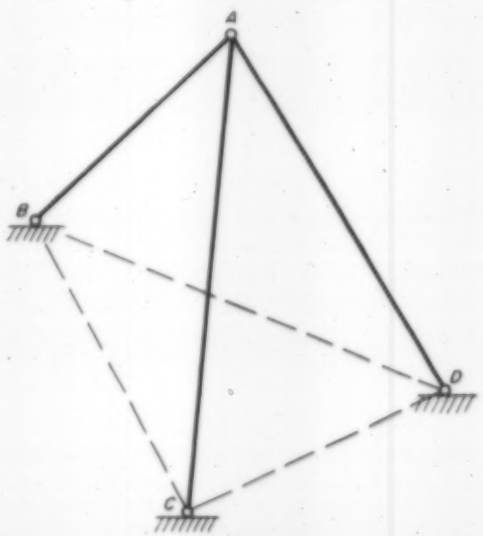
SIMPLE space structures of the type shown in *Fig.* 1 are often encountered in design. In aircraft powerplants and in rocket propulsion systems, for example, many components, including the prime mover itself, can be supported by simple, complex or compound structures[1] with long members loaded in tension or compression. Sometimes foundation effects permit negligible rotation at the structural joint, and the members can be conservatively analyzed as simple, pin-ended columns. Frequently, however, such a structure as shown in *Fig.* 1 is supported on a highly elastic foundation which might, of itself, be subject to distortion from load, leading to the imposition of secondary end rotation and end moments on the columns. Moreover, where light weight is important, optimum design requires that the compression member be loaded to a point near its critical value.

Actually, no column is either completely pin-ended (zero end moment) or completely clamped or restrained at the ends (maximum end moment). Some unknown degree of fixity exists between these limits. This article shows that where the column load is approximately 90 per cent of critical for pin ends, the degree of fixity at one joint of the column does not greatly affect the permissible rotation of the other joint. It will also be shown that there is a limiting joint rotation above which the column is unstable.

Basic Relationships: Consider a column of the

[1]References are tabulated at end of article.

Fig. 1—Simple support structure in which columns may be subject to secondary end rotations and moments



Nomenclature

A = Cross-sectional area of column, sq in.
D = Outside diameter of column, in.
E = Young's modulus of elasticity, psi
I = Moment of inertia of cross-sectional area of column about neutral axis, in.^{4}
k = Constant defined by Equation 5
L = Effective column length, in.
M = Bending moment, lb-in.
M_{max} = Maximum bending moment along column, lb-in.
P = Maximum allowable axial load on column, lb
P_{cr} = Critical axial column load (Euler), lb
s_y = Yield strength of column material, psi
t = Column wall thickness, in.
x = Distance from end of column to any point along the column, in.
y'' = Notation for second derivative
$Z = I/c$ = Column section modulus, in.^{3}
θ = End rotation of column, radians
$\phi(u)$ = Function defined by Equation 4
$\psi(u)$ = Function defined by Equation 3

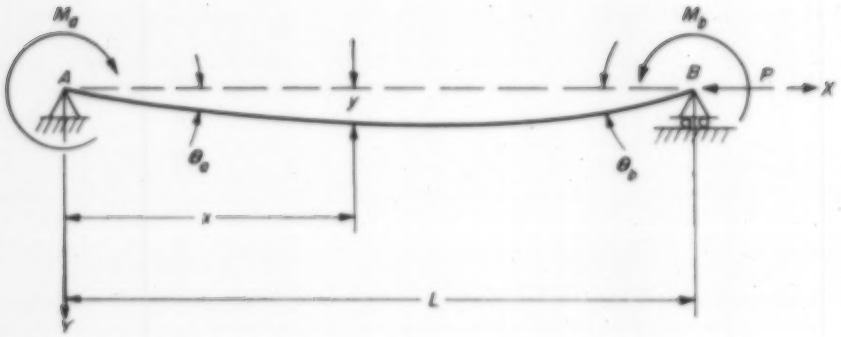


Fig. 2—Analysis of simple column under axial loading. Degree of fixity at *A* has influence on relationship between end moments and rotations

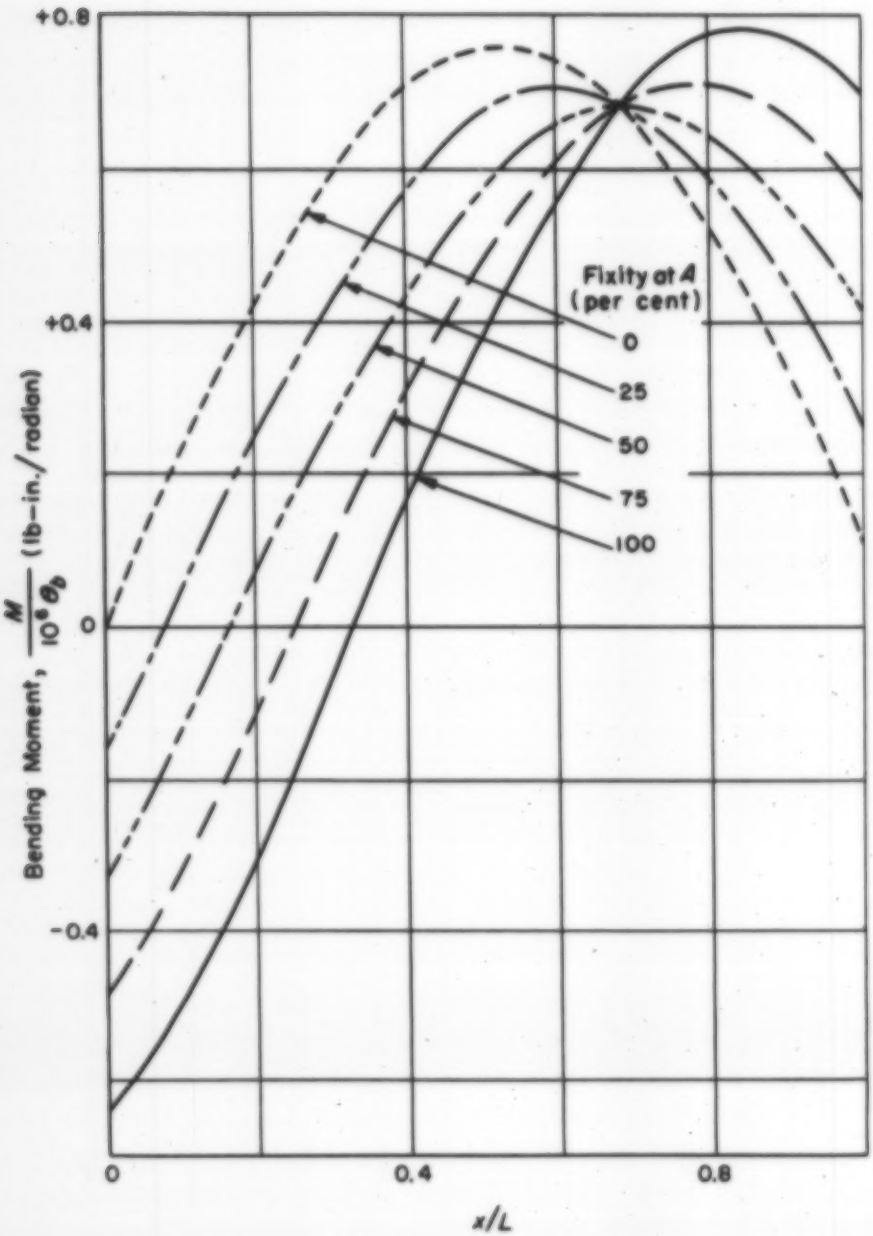


Fig. 3—Moment distribution curves for steel column of type shown in *Fig.* 2 with varying degrees of fixity at *A*

type shown in *Fig.* 2. This general case could, for example, represent a component of a rocket motor thrust-carrying element with A one of the points of juncture between motor and support and B one of the points of attachment to the airframe structure. Now the motor itself is rigid but the airframe structure is comparatively flexible. Thus, the airframe bulkhead and associated structure can deflect under load, imposing end rotation on the column AB.

Assume that the rotation, θ_b, imposed upon joint B can be calculated or measured optically. The end moments, M_a and M_b are not known. Five different degrees of fixity at end A will be considered: 100, 75, 50, 25 and zero per cent.

The relationships between end rotations and end moments are:[2]

$$\theta_a = \frac{M_a L}{3EI}[\psi(u)] + \frac{M_b L}{6EI}[\phi(u)] \quad (1)$$

$$\theta_b = \frac{M_b L}{3EI}[\psi(u)] + \frac{M_a L}{6EI}[\phi(u)] \quad (2)$$

where $\psi(u)$ and $\phi(u)$ are functions defined by

$$\psi(u) = \frac{3}{kL}\left[\frac{1}{kL} - \frac{1}{\tan(kL)}\right] \quad (3)$$

$$\phi(u) = \frac{6}{kL}\left[\frac{1}{\sin(kL)} - \frac{1}{kL}\right] \quad (4)$$

The constant k in this case is defined by

$$k = \sqrt{\frac{P}{EI}} \quad (5)$$

where P is the maximum applied load. Representative values of the functions $\psi(u)$ and $\phi(u)$, corresponding to values of kL within the range of normal design requirements, are listed for convenience in *Table* 1.

For $\theta_a = 0$, which corresponds to 100 per cent fixity at A, simultaneous solution of Equations 1 and 2 for M_a and M_b gives:

$$M_a = \frac{6EI\theta_b[\phi(u)]}{L\{[\phi(u)]^2 - 4[\psi(u)]^2\}} \quad (6)$$

$$M_b = \frac{1}{2[\psi(u)]}\left\{\frac{6EI\theta_b}{L} - M_a[\phi(u)]\right\} \quad (7)$$

From Equation 6, M_a can also be determined for all other degrees of fixity at A. For example, if A is 25 per cent rigid or fixed, M_a is then 25 per cent of what its value would be if A were 100 per cent fixed. From Equation 7 then, M_b can be found for all degrees of fixity at A. For convenience, M_a and M_b will be expressed in terms of θ_b.

Design Analysis: For illustration, it will be helpful to analyze a specific column design. Column specifications are: Material is SAE 4130 steel, L = 50 in., D = 2.00 in., t = 0.188-in., and $E = 30 \times 10^6$ psi. From these data, the moment of inertia is determined to be I = 0.444-in.^{4} and $EI = 13.32 \times 10^6$ lb-in.^{2}

From Euler's formula for long columns, the critical axial column load is $P_{cr} = (\pi^2 EI)/L^2 =$ 52,500 lb. Assuming $P = 0.90\ P_{cr}$ gives $P =$ 47,300 lb. From Equation 5, k = 0.0596 and, thus, kL = 2.98. From *Table* 1 then, $\phi(u)$ = 11.84 and $\psi(u)$ = 6.51. Finally, from Equations 6 and 7, for 100 per cent fixity at A, $M_a = -0.648(10^6)(\theta_b)$ and $M_b = 0.711(10^6)(\theta_b)$. Other values of M_a and M_b for different degrees of fixity at A are

Table 1—Representative Function Values*

kL	$\phi(u)$	$\psi(u)$	kL	$\phi(u)$	$\psi(u)$
2.36	2.5320	1.8195	2.74	4.8029	2.9778
2.38	2.5939	1.8516	2.76	5.0499	3.1027
2.40	2.6596	1.8854	2.78	5.3245	3.2414
2.42	2.7287	1.9212	2.80	5.6315	3.3963
2.44	2.8021	1.9589	2.82	5.9770	3.5704
2.46	2.8798	1.9989	2.84	6.3685	3.7676
2.48	2.9624	2.0413	2.86	6.8160	3.9928
2.50	3.0502	2.0864	2.88	7.3322	4.2525
2.52	3.1438	2.1343	2.90	7.9343	4.5550
2.54	3.2437	2.1855	2.92	8.6455	4.9121
2.56	3.3508	2.2402	2.94	9.4982	5.3401
2.58	3.4657	2.2988	2.96	10.5393	5.8622
2.60	3.5890	2.3618	2.98	11.8386	6.5134
2.62	3.7220	2.4295	3.00	13.5057	7.3486
2.64	3.8659	2.5027	3.02	15.7219	8.4583
2.66	4.0218	2.5819	3.04	18.8116	10.0049
2.68	4.1914	2.6680	3.06	23.4176	12.3096
2.70	4.3766	2.7619	3.08	31.0160	16.1165
2.72	4.5795	2.8648	3.10	45.9234	23.8659

*From Reference 2. Pages 499-505

Table 2—Effect of Column Fixity on End Moments

Fixity (per cent)	$M_a/(10^6\theta_b)$ (lb-in./radian)	$M_b/(10^6\theta_b)$ (lb-in./radian)
100	−0.648	0.711
75	−0.486	0.564
50	−0.324	0.417
25	−0.162	0.270
0	0	0.123

Table 3—Moment Distribution for 25 Per Cent End Fixity

x/L	kx (deg)	$k(L-x)$ (deg)	$\sin kx$	$\sin k(L-x)$	$M/(10^6\theta_b)$ (lb.-in./rad)
0	0	170.70	0	0.161	−0.162
0.2	34.14	136.56	0.561	0.688	+0.252
0.4	68.28	102.42	0.929	0.977	+0.580
0.6	102.42	68.28	0.977	0.929	+0.709
0.8	136.56	34.14	0.688	0.561	+0.591
1.0	170.70	0	0.161	0	+0.270

since its use often reduces the labor required to develop a dynamically desirable cam whenever the cam angle for the development region is large.

Step 1 of the profile development procedure is followed exactly as before. A desirable cam angle interval $\Delta\theta$ is thereby selected. However, since the cam angle for the development region is large, and since $\Delta\theta$ is always reasonably small, many displacement points will have to be calculated and subsequently adjusted. Hence, it is suggested that an initial development be made with a coarse cam angle interval. For instance, if $\Delta\theta$ represents the final cam angle interval as determined by Step 1, then the initial development might be made using an interval of $2\Delta\theta$ degrees. The initial development using this coarse interval is then carried out using Steps 2 and 3 as in *Example* 4. After this initial coarse development is complete, the stage is set for the final development.

The final development is carried out in the following manner. The displacement points from the initial development are recorded, and they represent fairly accurate approximations of the desired displacement values, every $2\Delta\theta$ degrees. The intermediate displacement values for this final development are approximated using straight-line interpolation. The result is a fairly good approximation of the desirable displacement points at the start of the final development. Acceleration factors are then calculated, and displacement adjustments are made using Step 3 as before. However, since fairly good approximations of the desirable displacement points are available at the start of the final development, a very small amount of labor has to be expended on the final development.

The same techniques can be carried still further. For instance, suppose the cam angle interval chosen under Step 1 is represented by $\Delta\theta$ degrees. The initial development might then be made using an interval of $8\Delta\theta$ degrees. The next development would then be made using an interval of $4\Delta\theta$ degrees, by using at the start of this development the displacement values from the initial development. The next development would then be made using an interval of $2\Delta\theta$ degrees, by using at the start of this development the displacement values from the previous development. The final development would then be made using an interval of $\Delta\theta$ degrees, by using at the start of this final development the displacement values from the previous development.

Jerk: In cam design, jerk is considered to be the time rate of change in acceleration—the derivative of acceleration with respect to time or the third derivative of displacement with respect to time. Avoidance of excessive jerk is just another way of stating avoidance of abrupt changes in acceleration. Hence, it is sometimes desirable to have an expression available for calculating jerk at a point. The following equation was derived in a manner similar to that used for deriving Equations 5 and 6:

$$\left(\frac{d^3y}{dt^3}\right)_0 = j_0 = 108\left(\frac{w}{\Delta\theta}\right)^3\left[(a_4 + 2a_1) - (a_3 + 2a_2)\right] \qquad (10)$$

where j_0 denotes the jerk at any point in question. The subscripts refer to five adjacent points having the order 3, 1, 0, 2, and 4 in the direction of increasing cam angle θ, and as before, 0 is the particular point in question.

Since actual follower body acceleration will fluctuate considerably from the primary acceleration due to machining tolerances in practical problems, a visual smoothing of the acceleration factors in the manner of *Example* 4 is generally considered to be sufficient. Hence, Equation 10 at this time seems to hold little practical significance.

Conclusions: The method developed and presented in this article for the problem of cam design makes use of the theory of finite differences. This theory has been similarly applied successfully for many years in the field of stress analysis with a high degree of accuracy.* For example, the author has used the method extensively in stress analysis and results so obtained have checked very closely with results obtained photoelastically. The error is generally less than 2 per cent. The author has applied the theory to cam design problems also, and it has proven to be a powerful and effective practical tool.

As this article shows, the method is simple. A cam profile can be developed having any desired type of dynamic characteristics and the designer needs only to be thoroughly familiar with the arithmetic process of correcting acceleration factors for follower body displacement adjustments. Since the basic method is arithmetic in nature, it can be mastered in a short period of time. Countless hours can be saved in designing cams, and the results will generally be far more satisfactory from a dynamics viewpoint.

*S. Timoshenko and J. N. Goodier—*Theory of Elasticity*, McGraw-Hill Book Co. Inc., New York, 1951. Pages 481-482.

"Engineering, above all other professions, contributes toward the betterment of human life by providing practical application to progressive scientific knowledge—the means whereby the creative imagination of the scientist is put to practical use—and by devising mechanical processes expedites the requirements of everyday life. Thus, he who tills the soil to produce the food we eat must look to the engineer to devise the means of irrigation, of mass production and of wide distribution; he who weaves the yarn to produce the clothes we wear must look to the engineer to devise the mechanics whereby may be met the mass needs of our expanding population; and he who builds the homes in which we live must look to the engineer to provide essential aids to human labor."—DOUGLAS MACARTHUR

Analyzing
COLUMN STABILITY

under varying end-load conditions

By G. Oakes
Research Engineer
Boeing Airplane Co.
Seattle, Wash.

SIMPLE space structures of the type shown in *Fig.* 1 are often encountered in design. In aircraft powerplants and in rocket propulsion systems, for example, many components, including the prime mover itself, can be supported by simple, complex or compound structures[1] with long members loaded in tension or compression. Sometimes foundation effects permit negligible rotation at the structural joint, and the members can be conservatively analyzed as simple, pin-ended columns. Frequently, however, such a structure as shown in *Fig.* 1 is supported on a highly elastic foundation which might, of itself, be subject to distortion from load, leading to the imposition of secondary end rotation and end moments on the columns. Moreover, where light weight is important, optimum design requires that the compression member be loaded to a point near its critical value.

Actually, no column is either completely pin-ended (zero end moment) or completely clamped or restrained at the ends (maximum end moment). Some unknown degree of fixity exists between these limits. This article shows that where the column load is approximately 90 per cent of critical for pin ends, the degree of fixity at one joint of the column does not greatly affect the permissible rotation of the other joint. It will also be shown that there is a limiting joint rotation above which the column is unstable.

Basic Relationships: Consider a column of the

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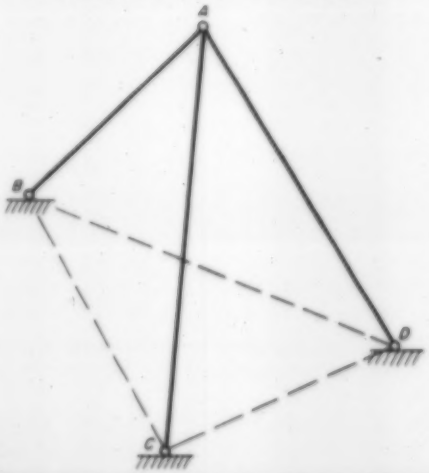
Fig. 1—Simple support structure in which columns may be subject to secondary end rotations and moments



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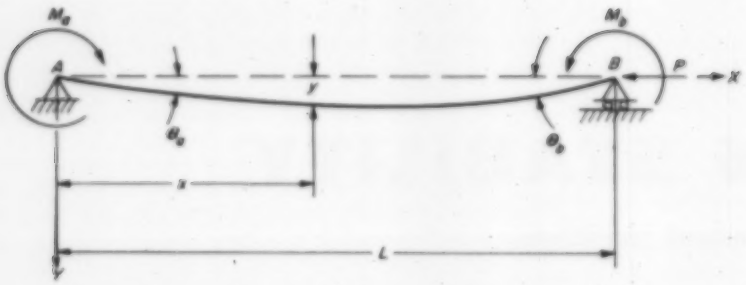

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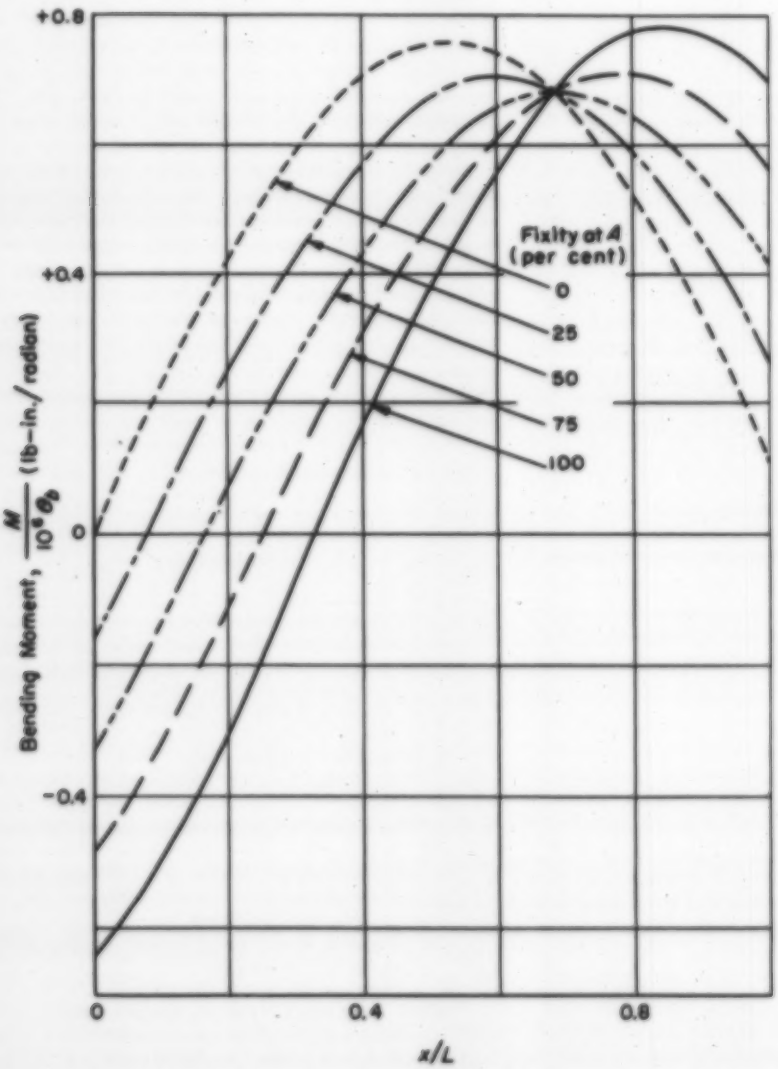

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type shown in *Fig. 2*. This general case could, for example, represent a component of a rocket motor thrust-carrying element with *A* one of the points of juncture between motor and support and *B* one of the points of attachment to the airframe structure. Now the motor itself is rigid but the airframe structure is comparatively flexible. Thus, the airframe bulkhead and associated structure can deflect under load, imposing end rotation on the column *AB*.

Assume that the rotation, θ_b, imposed upon joint *B* can be calculated or measured optically. The end moments, M_a and M_b are not known. Five different degrees of fixity at end *A* will be considered: 100, 75, 50, 25 and zero per cent.

The relationships between end rotations and end moments are:[2]

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The constant k in this case is defined by

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$$M_b = \frac{1}{2[\psi(u)]}\left\{\frac{6EI\theta_b}{L} - M_a\,[\phi(u)]\right\} \quad \ldots\ldots (7)$$

From Equation 6, M_a can also be determined for all other degrees of fixity at *A*. For example, if *A* is 25 per cent rigid or fixed, M_a is then 25 per cent of what its value would be if *A* were 100 per cent fixed. From Equation 7 then, M_b can be found for all degrees of fixity at *A*. For convenience, M_a and M_b will be expressed in terms of θ_b.

Design Analysis: For illustration, it will be helpful to analyze a specific column design. Column specifications are: Material is SAE 4130 steel, $L = 50$ in., $D = 2.00$ in., $t = 0.188$-in., and $E = 30 \times 10^6$ psi. From these data, the moment of inertia is determined to be $I = 0.444$-in.^{4} and $EI = 13.32 \times 10^6$ lb-in.^{2}

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kL	$\phi(u)$	$\psi(u)$	kL	$\phi(u)$	$\psi(u)$
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2.58	3.4657	2.2988	2.96	10.5393	5.8622
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2.68	4.1914	2.6680	3.06	23.4176	12.3096
2.70	4.3766	2.7619	3.08	31.0160	16.1105
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*From Reference 2. Pages 499-505

Table 2—Effect of Column Fixity on End Moments

Fixity (per cent)	$M_a/(10^6\theta_b)$ (lb-in./radian)	$M_b/(10^6\theta_b)$ (lb-in./radian)
100	−0.648	0.711
75	−0.486	0.564
50	−0.324	0.417
25	−0.162	0.270
0	0	0.123

Table 3—Moment Distribution for 25 Per Cent End Fixity

x/L	kx (deg)	$k(L-x)$ (deg)	$\sin kx$	$\sin k(L-x)$	$M/(10^6\theta_b)$ (lb.-in./rad)
0	0	170.70	0	0.161	−0.162
0.2	34.14	136.56	0.561	0.688	+0.252
0.4	68.28	102.42	0.929	0.977	+0.580
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0.8	136.56	34.14	0.688	0.561	+0.591
1.0	170.70	0	0.161	0	+0.270

Table 4—Maximum Bending Moments

Fixity (per cent)	$\frac{M_a}{10^6\theta_b \sin kL}$	$\frac{M_b}{10^6\theta_b \sin kL}$	tan kx	sin kx	sin $k(L-x)$	$\frac{M_{max}}{10^6\,\theta_b}$ (lb-in./rad)
100	−4.020	4.410	−0.681	0.563	0.422	0.785
75	−3.015	3.500	−1.074	0.732	0.612	0.713
50	−2.010	2.590	−1.860	0.881	0.792	0.687
25	−1.005	1.680	−4.220	0.972	0.922	0.709
0	0	0.770	∞	1.000	0.987	0.770

Table 5—Maximum Allowable End Rotation

Fixity (per cent)	Maximum End Rotation, θ_b (mil radians)
100	17.3
75	19.0
50	19.8
25	19.3
0	17.7

given in *Table* 2.

Data for plotting moment distribution curves, *Fig.* 3, can be determined from

$$M = EIy'' = \left\{ M_b \left(\frac{\sin kx}{\sin kL} \right) + M_a \left[\frac{\sin k(L-x)}{\sin kL} \right] \right\} \quad (8)$$

which is based on the second derivative of the deflection curve for a compressed beam with end moments. The method of tabulating data is illustrated in *Table* 3, which gives the calculation results for the condition of 25 per cent fixity at *A*. Values of kx are found as follows: At $x/L = 0.2$, $kx = 0.2\ kL = 0.596$-radian $= 34.14$ degrees

For any degree of end fixity, the value of kx at which the moment will be a maximum may be determined by differentiating Equation 8 and setting the derivative equal to zero. The general expression obtained in this way is

$$\tan kx = \frac{M_b - M_a \cos kL}{M_a \sin kL} \quad (9)$$

From trigonometric relationships between tan kx, sin kx and sin $k(L-x)$, the maximum moment, M_{max}, can now be determined for each degree of fixity. Values of M_{max} for the five representative degrees of end fixity used here are given in *Table* 4.

The criterion for column stability is expressed as

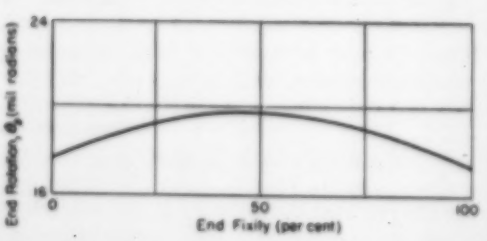
$$s_y = \frac{P}{A} + \frac{M_{max}}{Z} \quad (10)$$

For all practical purposes, a column will be considered to have failed when the yield point is reached.

In the example under discussion, basic data for determining column stability are: $s_y = 75{,}000$ psi, $P = 47{,}300$ lb, $A = 1.068$ sq in. and $Z = 0.444$ in.^{3} From Equation 10, using these data, the maximum allowable bending moment is $M_{max} = 13{,}600$ lb-in. Since these moments are expressed in terms of θ_b in *Table* 4, the maximum allowable rotation at *B* can be related to the degree of fixity at *A*. These relationships are shown in *Table* 5 and *Fig.* 4.

While the example solution given in this article does not constitute a rigorous proof, it suggests a method of analysis that can be easily and quickly applied to any column of the type considered. It is interesting to note that in this example the limiting end rotation, θ_b, is not highly sensitive to the degree of fixity at *A*, the variation from highest to lowest value being only approximately 14.5 per cent.

Fig. 4—Maximum allowable end rotation for different degrees of fixity at *A* for steel column analyzed in *Fig.* 3



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1. S. Timoshenko and D. H. Young—*Theory of Structures*, McGraw-Hill Book Co. Inc., New York, 1945
2. S. Timoshenko—*Theory of Elastic Stability*, McGraw-Hill Book Co. Inc., New York, 1936

DESIGN ABSTRACTS

Determining Bolt Tension

from torque applied to the nut

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FOR many applications bolts must be properly tightened in order to obtain maximum efficiency of the fastener. Frequently, adjustment of tightening tension is obtained by control of the torque applied to the bolt head or nut.

The torque required to produce a certain bolt tension can be estimated from the following approximate equation:

$$T = KDW \qquad (1)$$

where T = torque, lb-in.; K = torque coefficient (approx 0.2); D = nominal bolt size, in.; and W = bolt tension, lb.

Coefficient K is about 0.2 as a first guess, but there can be considerable variation, and the value should be used only as a preliminary estimate.

The more exact value of K is expressed by the following equation, provided there is no thread interference such as by a locknut or wrench-tight thread fit.

$$K = u_B \frac{R_B}{D} + \frac{R_T}{D}\left(\frac{u_T \sec B + \tan C}{1 - u_T \sec B \tan C}\right) \qquad (2)$$

where u_B = coefficient of friction at bearing face of nut or bolt; u_T = coefficient of friction at thread contact surfaces; R_B = effective radius of action of frictional forces on bearing face, in.; R_T = effective radius of action of frictional forces on thread surfaces, in.; B = thread half-angle (30 degrees for 60-degree thread; sec B = 1.15), degrees; and C = helix angle of thread, degrees.

Table 1—Torque Coefficients, K, for Semifinished Hex Nuts

Bolt Size	Theoretical* K	Measured K (average) High-Point Torque	Mid-Point Torque
¼-20	0.210	0.243	0.267
¼-28	0.205	0.216	0.231
⅜-16	0.210	0.206	0.186
⅜-24	0.205	0.194	0.183
⅜-16	0.204	0.200	0.247
⅜-24	0.198	0.192	0.234
½-14	0.205	0.217	0.224
½-20	0.200	0.194	0.190
½-13	0.201	0.205	0.158
½-20	0.195	0.187	0.205
⅝-12	0.198	0.194	0.214
⅝-18	0.193	0.196	0.207
⅝-11	0.199	0.173	0.196
⅝-18	0.193	0.183	0.175
¾-10	0.194	0.189	0.173
¾-16	0.189	0.170	0.180
⅞-9	0.194	0.161	0.194
⅞-14	0.189	0.171	0.178
1-8	0.193	0.188	0.204
1-14	0.188	0.161	0.167
Average	0.198	0.191	0.201

*Computed with coefficient of friction of 0.15 and the dimensions of American Standard Regular Semifinished Hexagon Nuts.

For threads used for fasteners, the denominator of the bracketed term is unity within ½ per cent, so

$$K = u_B \frac{R_B}{D} + u_T \frac{R_T}{D} \sec B + \frac{R_T}{D} \tan C = K_1 + K_2 + K_3 \qquad (3)$$

Relative values of K_1, K_2 and K_3 can be seen by inserting fair average values such as $R_B/D = 0.65$; $u_B = u_T = 0.15$; $R_T/D = 0.45$; sec $B = 1.15$; tan $C = 0.04$.

$$K = 0.098 + 0.078 + 0.018 = 0.194$$

$$\frac{100\,K}{0.194} = 50.5 + 40.2 + 9.3$$

$$= 100 \text{ per cent}$$

So, it can be estimated that K_1, K_2 and K_3 contribute roughly 50, 40 and 10 per cent respectively to the torque coefficient K.

Torque Coefficients: Coefficient K_1 represents the unit torque wasted by friction on the bearing face of the nut or bolt. This is about 50 per cent of the total

torque. K_1 varies with the coefficient of bearing face friction (0.12-0.20) and also with the effective radius of the bearing face, R_B. The radius R_B is approximately the average radius of the bearing face if contact pressure is uniform. Exact value of R_B for uniform contact pressure is

$$R_B = \frac{2}{3}\left(\frac{R_o^3 - R_i^3}{R_o^2 - R_i^2}\right)$$

where R_o and R_i are the outer and inner bearing radii, respectively.

If the bearing face is not true and flat and the pressure uniform, R_B may vary from the inner radius of the bearing face to the outer radius.

Coefficient K_2 represents the unit torque wasted by friction on the contact flanks of the threads. This represents about 40 per cent of the total torque. K_2 varies with the coefficient of thread friction (0.12-0.20) and also with the radius of action of friction on thread faces, R_T. Radius R_T is approximately the pitch radius of the screw thread if thread contact pressure is uniform. If contact pressure is not uniform, R_T may vary from the inner to the outer radius of contact of threads. Radius R_T also will differ between coarse threads and fine threads, being larger for fine threads and resulting in higher torque. K_2 is also slightly variable with bolt tension because of increase of angle B due to thread bending under load. The increase in angle B may be considerable at loads near thread failure by stripping.

Coefficient K_3 represents the useful torque producing bolt tension. This is about 10 per cent of the total torque. K_3 varies with R_T and with the helix angle of the thread. The helix angle, C, varies with the bolt size, being somewhat larger for smaller bolt sizes. It also varies between coarse and fine threads, being slightly larger for coarse threads.

Values of K as computed by Equation 2 are shown in *Table* 1, using $u_B = u_T = 0.15$; R_B = average radius for regular semifinished hexagon nuts; R_T = pitch radius of threads; sec B = 1.15; and tan C = value for appropriate thread. The table also shows average experimental values determined from a large number of bolts from several different manufacturers. There is good agreement between the computed and average experimental values. Tension produced in a specific bolt may vary considerably from the average of a group. Extreme variations may be plus or minus 30 per cent, and the average deviation is of the order of 6 to 7 per cent.

Table 2—Torque Coefficients for Various Styles of Bolts and Nuts

Size	Finished Hex Nut (K_1)	Finished Hex Nut (K_2)	Finished Hex Nut (K_3)	Finished Hex Nut (K)	Finished Hex Bolt (K)	Heavy Hex Bolt or Nut (K)
¼-20	0.1055	0.0753	0.0318	0.213	0.213	0.223
¼-8	0.1055	0.0786	0.0227	0.207	0.207	0.215
5/16-18	0.0993	0.0766	0.0284	0.204	0.204	0.213
5/16-24	0.0993	0.0790	0.0212	0.200	0.200	0.208
⅜-16	0.0950	0.0772	0.0285	0.199	0.199	0.213
⅜-24	0.0950	0.0802	0.0178	0.193	0.193	0.207
7/16-14	0.0980	0.0772	0.0280	0.201	0.196	0.207
7/16-20	0.0980	0.0800	0.0181	0.196	0.190	0.202
½-13	0.0950	0.0780	0.0245	0.198	0.198	0.208
½-20	0.0950	0.0811	0.0139	0.192	0.192	0.203
9/16-12	0.0970	0.0781	0.0235	0.199	0.195	0.202
9/16-18	0.0970	0.0811	0.0187	0.194	0.191	0.197
⅝-11	0.0950	0.0783	0.0231	0.196	0.196	0.205
⅝-18	0.0950	0.0816	0.0141	0.191	0.191	0.199
¾-10	0.0950	0.0790	0.0212	0.195	0.195	0.203
¾-16	0.0950	0.0819	0.0133	0.190	0.190	0.198
⅞-9	0.0950	0.0793	0.0201	0.194	0.194	0.201
⅞-14	0.0950	0.0819	0.0130	0.190	0.190	0.196
1-8	0.0950	0.0795	0.0199	0.194	0.194	0.200
1-14	0.0950	0.0826	0.0109	0.189	0.189	0.194
Average				0.197		0.205

Conclusions:

1. Equation 1, using $K = 0.2$, gives a fair preliminary estimate of torque required to produce a given tension regardless of bolt size or thread pitch. This applies only to semifinished hexagon nuts (or bolts if bolt is torqued) having a width across flats of about 1.5 times the nominal diameter; to threads free of interference such as provided by a locknut or wrench-tight thread fit; to steel bolts and nuts as normally produced and without added plating or lubrication; and to applications where the torqued bearing face of the fastener is in contact with relatively smooth, unplated, nonlubricated steel surfaces.

2. A more exact theoretical expression of K can be obtained from Equation 3. Computed values of K for various styles of bolts and nuts are given in *Table* 2, using coefficient of friction $u_B = u_T = 0.15$.

3. There is considerable variation in the value of K from bolt to bolt even when conditions are well controlled, because of variations in coefficient of friction. Therefore, where closer control of tension is required, the value of K should be determined experimentally for the particular application. Even so, K will vary considerably because of chance variations in friction.

4. There is little difference in K between coarse and fine threads—the value for coarse threads being only about 2½ per cent higher than for fine threads, which is negligible. This is surprising to many people who feel that the sharp helix angle of fine threads should produce tension with considerably less torque effort. This is not true, because 90 per cent of the torque effort is wasted in friction regardless of the thread pitch. Incidentally, this high frictional effect works both ways and, if high bolt tension is maintained, helps prevent loosening of the fastener.

5. The value of K as estimated does not apply at or near the failure point of the bolt-nut combination, particularly if the imminent failure is by stripping of threads. In this situation, there may be

galling of contact surfaces with greatly increased K. Also, the thread angle, B, becomes greatly distorted, further increasing K. These influences, added to the normal variations in K, result in a very indeterminate value of K. From this, it is evident that the torque at failure cannot be taken as any reliable measure of the strength of the fastener.

From "Torque for Bolts and Nuts" in Industrial Fasteners Institute Fasteners, *Volume* 10, *Number* 1.

Design factors for

Ultrasonic Impact Grinding

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THERE is nothing really new about the impact grinding principle. It has long been known that power transferred through a metal punch with a soft tool tip to a hard abrasive can make cavities in materials that are harder than the tool tip. Only ultrasonic impact grinding is new. This modern application of an old idea substitutes for hand power an ultrasonic hammer that strikes 25,000 times a second. The result is a grinding method which can cut a variety of hard, brittle materials with soft, inexpensive tools.

The head unit of an ultrasonic impact grinder, *Fig.* 1, contains an electromechanical transducer which converts the alternating electrical current supplied by the driver unit to mechanical vibrations of the same frequency—25,000 per second. The frequency of these vibrations, being above 16,000 cycles per second, is in the inaudible ultrasonic range. This transformation of electrical energy to mechanical is accomplished through a laminated nickel stack. When subjected to a magnetic field, nickel and certain other metals and alloys display a property called magnetostriction—a changing in physical dimensions with changes in flux density. A nickel rod, for instance, will shorten as the flux density of the magnetic field increases. By selecting an appropriate bias flux, the rod may be made to vibrate with changes in flux density.

The vibrations are amplified and transmitted to the cutting tool by means of a tool cone to which the

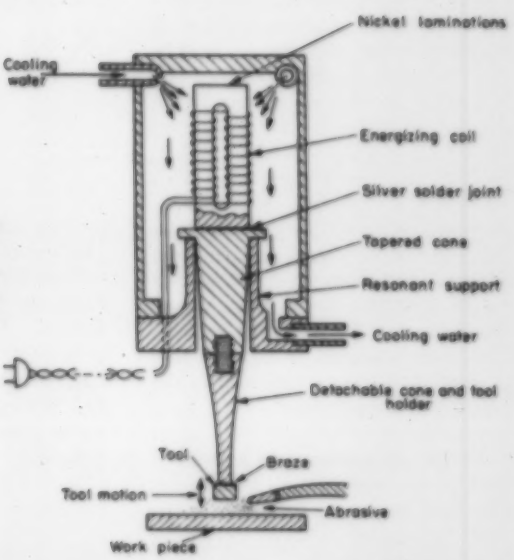

Fig. 1—Head unit of ultrasonic impact grinder showing transducer which converts ac current to mechanical vibrations

Fig. 2—Tool tips of various shapes designed to provide high amplitude for ultrasonic impact grinding

tool is attached. The resulting vibration of the tool is entirely perpendicular to the tool face. No side-to-side motion occurs. A very small space filled with abrasive fluid develops between the vibrating tool face and the work when the machine is operating. The tiny particles of abrasive are accelerated by the motion of the tool tip, and driven with tremendous impact against the work, thereby chipping or grinding an exact counterpart of the tool face into the work.

The work is fed up to the tool to maintain constant grinding force between the two. Despite the fact that the abrasive particles strike the work with impact forces up to 150,000 times their own weight, the grinding force required seldom exceeds 10 pounds. This small force, together with the vibrating nature of the process, plus the absence of direct tool to work contact and the presence of the liquid abrasive, mean that impact grinding is a cold cutting process. The work material is not stressed or distorted in any way and is not raised in temperature.

Design Considerations: From a design or production standpoint, the tool cones and tips are the most important parts of the ultrasonic impact grinder. With them, the counterpart of the shape or design on the face of the tool is reproduced in the work material. These tool tips can be made of cold-rolled or unhardened tool steel —even copper and lead.

Soft tool tips do wear. It all depends on the nature of the material being cut. Rate of wear varies from one part in 200 for glass down to one part in one for tungsten carbide. However, since cutting action and wear are both vertical in direction and uniform in depth, there is no change in the shape or contour of the face of the tool or its reproduction in the material. Notice the shapes of the tool cones in *Fig.* 2. Each is designed to provide the highest possible amplitude at the tool tip. The smaller the tool tip, the greater the amplitude and, therefore, the faster the cutting rate.

Fig. 3—Finished parts that have been machined by ultrasonic impact grinding

This principle imposes restrictions on the size of the area to be cut. In most metals, the limit is about 1¾ square inches. In easy-to-cut materials, such as carbon and glass, areas as large as three square inches can be machined.

It is important, of course, to use the right type and size of abrasive in impact grinding. Boron carbide is first choice. However, with some materials, silicon carbide and aluminum oxide have been used successfully. The size of grit depends on the particular application. Grits ranging from 180 to 800, with diameters varying between 0.0034 and 0.00012 of an inch have been used. With an 800 grit abrasive, surface finishes between 8 and 10 microinches have been obtained.

Some of the jobs the Raytheon impact grinder has done since 1950 can be seen in *Fig.* 3. This method was first introduced to the jewelry industry for making round and shaped holes in semiprecious and precious gems. Today, this machine is successfully cutting, shaping, trepanning, slicing, drilling, engraving, and grinding many materials to tolerances of ±0.0002-inch and finishes to 8 microinches. High precision is possible since the work is not chipped, spun, heated, stressed, or distorted in any way.

Fig. 4 — Carbide "Raytheon" stamp, right, which was reproduced from an engraved cold-rolled steel matrix in one minute, and a smaller steel heading die, left, both made by the ultrasonic impact method

At present, materials successfully machined by ultrasonic impact grinding include ceramics, ferrite, germanium, glass, glass-bonded mica, granite, graphite, hardened steel, mother-of-pearl, plaster of

• Big pulverizing mills made by Raymond Division, Combustion Engineering, Inc., depend on Johnson Bronze Bearings for trouble-free performance the world over. At right is a high side roller mill installed in the Kaiser Gypsum Wallboard Plant at Seattle.

Where One Bearing Can Keep Whole Plant From Shutdown

When you're investing up to $85,000 for a pulverizing mill around which you're going to build an entire plant, you expect to get equipment which will give long, trouble-free performance.

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Because bearings play such an essential role in the operation of pulverizing mills, the Raymond Division, Combustion Engineering, Inc., has relied for more than 30 years on cast bronze bearings made by the Johnson Bronze Company of New Castle, Pa.

Johnson Bronze bearings rate high with this Chicago manufacturer because they can be depended upon to keep these expensive units on the job day in and day out and because they are made just the way Raymond Division specifies. That means a very low rejection rate and faster production.

Take the big bronze bearings Johnson makes for journals on a pulverizing mill. They are made to a tolerance of .002 of an inch. Because Johnson consistently meets this specification, the time required to fit the bearing is held to a minimum. A few taps with a rawhide mallet usually slips the bearing into its position.

If your product demands uniformity, investigate Johnson Bronze products. You can depend on them for faster production and longer life in use. Skilled engineers are available to help you decide what type of bearing you need to get the best possible results at lowest cost. Johnson Bronze Company, 525 S. Mill Street, New Castle, Pa.

Johnson Bearings

LEDALOYL (powder metallurgy) • ALUMINUM ON STEEL • BRONZE ON STEEL • STEEL AND BABBITT • CAST BRONZE

Paris, quartz, rexalloy, ruby, sapphire, silicon, stellite, tungsten and tungsten carbide and some of the softer metals such as aluminum, brass and copper.

Carbide stamps, like the "Raytheon" stamp in *Fig.* 4, could never be made before the advent of ultrasonic impact grinding. This particular stamp was reproduced from an engraved cold-rolled steel matrix in less than one minute. One manufacturer is making carbide stamps in less than 15 seconds each.

Another raised-surface application is typified by the steel heading die also shown in *Fig.* 4. It is used for making recessed-head screws. This die was made in about 15 minutes on an impact grinder with a tool made of cold-rolled steel. The die blank has a conical projection. The impact grinder shapes the flutes and the land on the face of the die and gives both a very fine finish.

From a paper entitled "Ultrasonic Impact Grinding" presented at the Annual Machine Tool Electrification Forum, sponsored by Westinghouse Electric Corp., Buffalo, N. Y., April, 1955.

Developing new products from

A Patent Collection

By Jean L. Carpenter

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THE engineer is often faced with unfamilar problems concerning the development or improvement of a product or process about which he knows little or nothing. As a result, he does not know where to begin the development or where to look for pertinent background material. One way that he might start is to make a study of classified patents in the Patent Office. To do this he can obtain what is known as a patent "art collection," that is, the most pertinent patents relating to the product or process. A collection of patents can be made in a short time (either by a professional searcher or by the engineer himself) which provide him with a wealth of information relating to the product or process in which he is interested.

In order to illustrate the manner in which the engineer might employ these patent art collections, assume that he is faced with the development of a variable-speed fan drive which is to be responsive to engine temperature in order to provide uniform cooling for an internal combustion engine at various engine speeds and ambient temperatures. He might first request a preliminary patent collection on this type of drive.

Upon obtaining the collection he no doubt would be surprised to find that there are huge numbers of patents on different types of thermally responsive variable fan drives. These patents would include friction-type clutches in which the sliding frictional forces between the clutch plates of the driving and driven members are varied with engine temperature. They would include hydraulic couplings which fill and empty to vary slip between driving and driven members in response to engine temperature, eddy-current clutches whose excitation is varied according to engine temperature, and so on.

The engineer might then decide that an eddy-current coupling would be the most desirable for his needs and order a further collection of patents on only that type. Now he can accurately determine just how such eddy-current variable speed drives are constructed and work, as well as the problems which they were developed to overcome. A careful analysis of the patents will teach him which features are most desirable and may lead him to combine them in his own drive. He will no doubt observe defects to be avoided and, what is even more important, will be encouraged to employ creative thinking which is likely to result in a superior drive with novel features.

Avoiding Infringement: Another benefit obtained in the study of patents prior to undertaking a new development is that the engineer, through the aid of a competent patent attorney, may determine the scope of coverage of unexpired patents in the field and engineer his new development to avoid the areas "staked out" and protected by these patents. This has the advantage of requiring a considerable amount of creative thinking on his part.

It may also avoid later changes in the product, changes in tooling, or changes in production schedules, which might be required if a product is developed without a proper interpretation of these patents.

By their very nature and because of the requirement of certain of the patent laws, patents often provide more accurate, complete, and up-to-date information on new developments than do most textbooks or technical publications. In fact, in certain cases, such as electronic computing machines, one of the very few places an engineer can obtain any detailed, accurate information is in the patents taken out on such machines.

From "Patents May be Used by the Engineer as an Excellent Source of Technical Information" in General Motors Engineering Journal, ***March-April,*** 1955.

HELPFUL LITERATURE

FOR DESIGN EXECUTIVES

Vacuum Melted Metals

General Electric Co., Carboloy Dept.—Metals and alloys melted in a vacuum are produced with close composition control and free from inclusions or impurities. General and technical information on these metals, their applications, properties and processing data are given in this 22-page bulletin VM-101. Design data are included on two new high temperature alloys.

Speed Reducers

Michigan Tool Co., Cone-Drive Gears Div.—Bulletin CD-323. Design data, service factors, ratings, specifications and other data are presented.

Electric Valves

Hays Mfg. Co.—8-page illustrated bulletin 1500 contains application data and dimension prints on line of Electrofio two-way normally-closed solenoid valves for hot or cold water at pressures up to 150 psi. These controls are available in ⅜, ½ and 1¼-in. sizes, with coils for all commercial voltages.

Cam Follower Bearing

McGill Mfg. Co.—Design and performance features of the Sealed Camrol cam follower and bearing are described in 4-page illustrated bulletin SCF-55. Mounting details and data of cam follower stud-housing fits are included.

Cold Finished Steel Terms

Carpenter Steel Co.—32-page illustrated "Simplified Steel Terms and Engineering Data" is a virtual dictionary of terms of value to those who buy or specify the use of cold finished steel bars. Terms defined range from annealing and Austempering through isothermal quenching and macro-etching to Spheroidizing, stress relieving and yield strength. Over 180 terms are covered.

Ceramic Magnets

Indiana Steel Products Co.—The characteristics, design and application of Index 1 lightweight low-cost nonmetallic ceramic permanent magnet are subject of 4-page illustrated catalog 13. Light weight and high coercive force of this magnet adapt it for use in indicating gages, magnetic couplings, filters, instrumentation and miscellaneous holding applications.

Hydraulic Control Valves

Hydraulic Press Mfg. Co.—60-page illustrated catalog 821 deals with model 3000 stacked series directional and functional valves for 3000-psi hydraulic power service. Data are presented on four and two-way controls, rotary pilot valves, relief controls, flow and check valves, and pressure reducing and sequence valves with a complete range of actuating and design variations.

Assembly & Run-in Techniques

Acheson Colloids Co.—Photographs, diagrams, charts and other information are contained in 4-page illustrated bulletin 421 to explain the use of colloidal graphite in the assembly and run-in of engines and machinery. "dag" colloidal graphite is used for this purpose principally in the form of a petroleum dispersion.

Machine Tool Motors & Drives

Reliance Electric & Engineering Co.—12-page illustrated bulletin 1750 is entitled "Motors and Drives for Machine Tool Industry." Details are given on motors with special shafts and flanges, for mechanical construction, with rolled ball thrust design, for fast reversing, for variable speed and with other characteristics to adapt them for incorporation in or for driving machine tools. Also covered is a complete line of standard motors and adjustable speed drives.

10. Variable Pitch Sheaves

Allis-Chalmers Mfg. Co.—Vari-Pitch variable pitch pulleys and controls are subject of 4-page illustrated bulletin 20B6082C. Stationary and motion controls are described which provide means for adjusting speeds of drives when machines are stopped and when machines are operating. Sheaves are reported to provide up to 75 per cent speed variations in capacities up to 600 hp.

11. Gasoline Engine

Ford Motor Co., Industrial Engine Dept.—6-page illustrated bulletin IE-7522 tabulates complete specifications and gives design and performance data on the new Ford 239 model JG V-8 heavy duty industrial engine and power unit. This gasoline engine develops 189 dynamic brake horsepower at 3600 rpm.

12. Electric Heating Elements

Cutler Hammer, Inc.—"Electrical Heating Elements" is title of 24-page illustrated manual which gives design and application data on elements for use in industrial, commercial and domestic equipment and applications. Described are tubular, strip, water and oil immersion types and domestic water heating elements in standard and custom-made designs.

13. Ball Bearing Pillow Blocks

Dodge Mfg. Corp.—Designed expressly for medium duty service, SCM ball bearing pillow blocks and flange cartridge mounts are described in detail in 32-page illustrated catalog A-633. Tabular data include engineering drawings, dimensions, shaft sizes, weights, radial load ratings and lists prices on these as well as on the complete line of Dodge SC ball and Dodge-Timken roller bearings.

14. Hydraulic Power Units

New York Air Brake Co., Dudco Div.—Data on the PF100 series of 2000-psi variable-delivery hydraulic power units are given in 4-page illustrated bulletin DP-308. These power units combine double pumps with integral valve panels.

15. Bellows & Flexible Metal Hose

Flexonics Corp.—16-page illustrated catalog 150 has been prepared to aid the designer in the selection and application of the proper bellows or metal hose for specific jobs. Specifications are given on Flexon Rex-Weld flexible metal hose with up to 14-in. ID. Data are given on wide range of sizes of bellows in stainless, brass and phosphor bronze types with up to 12⅞-in. OD.

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16. Swivel Joints for Piping

Barco Mfg. Co.—Flexible ball, swing, swivel, revolving and other types of movable joints for use in piping for power, process, heating, chemical and hydraulic service are detailed in 12-page illustrated bulletin 265-B. These self-aligning swivel joints afford flexibility in piping for all types of machines.

17. Form-Dipped Rubber Parts

Automotive Rubber Co.—Data chart on rubber insulated metal parts such as clips, clamps and grommets as well as on rubber parts produced by the Form-Dipping process is a 4-page illustrated bulletin. Form-dipped parts include seals, boots, guards and wiring harnesses.

18. Atomic Industry Products

Farrel-Birmingham Co. — "Products and Services for the Atomic Energy Industry" is the title of 20-page illustrated bulletin 274. It describes this company's products which have been developed for this field such as radiation shielding, reactor components, transfer and storage casks, decontamination cells and remotely controlled manipulation equipment. Company's facilities for custom manufacture are described also.

19. Electric Motors

Century Electric Co.—Performance Rated electric motors in 1 to 30-hp sizes are detailed as to their mechanical variations, construction and performance in 12-page illustrated bulletin 6-1 PI. Data are given on standard open, totally enclosed fan cooled, face mounted, flange mounted and up to 5-hp cushion base units.

20. Socket Screw Products

Strong, Carlisle & Hammond Co., Mac-It Screw Div.—Dimension standards, standard sizes, physical properties, recommended tightening torque and suggested applications for seven types of Mac-It socket screws are included in data file. Types covered are hollow pipe plugs, hollow lock screws, stripper bolts, hex socket keys, button head socket cap screws, flat head socket cap screws, socket head cap screws and hollow set screws.

21. Self-Synchronous Motors

Electric Indicator Co.—Line of Elinco self-synchronous motors which are designed to provide accurate dependable performance in commercial and military applications for remote indication, computation and process control is subject of 6-page illustrated folder EI-5A.

22. Aluminum Alloys

Peter A. Frasse & Co.—General properties, fabricating characteristics, typical applications and available size range of each of a line of aluminum alloys are contained in illustrated bulletin "Aluminum Products." Also presented are alloy designation, weight comparison and temper designation charts.

23. Bearings & Bearing Materials

American Crucible Products Co.—Two illustrated bulletins give data on Promet bronze bearings and materials. First is 12-page booklet which describes bronze bushings, bearings, bar stock and babbitt metal. What Promet bronze is and its advantages are related.

24. Rubber-Phenolic Design Data

General Electric Co., Chemical Materials Dept.—The sixth edition of the "G-E Design File for Rubber Phenolics" is designated as bulletin CDC-237A. It contains 25 case histories and also serves as a convenient handbook for evaluation and use of rubber-phenolic molding materials.

25. Miniature Timers

A. W. Haydon Co.—Data on line of miniature hermetically sealed repeat cycle timers are content of 2-page illustrated bulletin A.W.H. RC200. Cycling time, timing accuracy and determination of timing tolerances are covered.

26. High Strength Steels

Republic Steel Corp.—Chemical composition, mechanical properties, fabricating practices, cold forming, rolling limits and applications for Republic 50 high strength steel are detailed in 4-page folder ADV-688. Similar data for Republic 65 and 70 high strength alloy steels are contained in 4-page folder ADV-[illegible].

27. Specialized Scales

Exact Weight Scale Co.—Few of the specialized model of scales for [illegible] blending, compounding, sorting, checking, inspecting, packaging and stacking are outlined in illustrated mailing piece. [illegible] included for requesting more data on scales for specific purposes.

28. Packings for Steel Mills

E. F. Houghton & Co.—Types of packings used for the many hydraulic and pneumatic installations found in the steel industry are described in illustrated bulletin. Cup, V, U, cup, flange, O-ring, back-up washer, gasket, diaphragm and special shape packings of several materials. Application data are included along with engineering recommendations.

29. Spring Design Data

Hunter Spring Co.—Basic considerations in designing precision springs are discussed and illustrated in 8-page engineering study. Charts, drawings, graphs and formulas are used to describe various types of springs and design criteria. Eight ways to specify compression and extension springs are presented.

30. Pneumatic-Hydraulic Unit

National Pneumatic Co., Industrial Automation & Controls Div.—8-page illustrated bulletin IC-2.3 contains data on the NP Power Unit cylinder which operates on 500-psi maximum oil or 200-psi maximum air pressure. Various mounting types are covered. Bulletin, which with 4 pages contains details on [illegible] pneumatic-hydraulic actuators and controls.

31. Oil Seal

Johns-Manville—Data on selection, application and installation of Clipper oil seals are found in 28-page illustrated manual [illegible]. New LPD and RPD extruded and molded slingers and end face seals are detailed. Essential data are in tabular form for ease of use. Documental case histories are included.

32. Casting Process

Lebanon Steel Foundry—Ceramicast, a molding process that utilizes ceramic molds to produce castings with smooth surfaces, intricate shapes, thin metal sections, close clearances, minimum machining costs and low production costs, is subject of illustrated bulletin. Process is adaptable to almost any casting size or alloy.

33. Rivet Selection

Milford Rivet Co.—This 4 x 9-in. "slide rule" rivet selector gives specific dimensions, clinch allowances and clearances for standard rivets. Sections are devoted to bifurcated, cutlery, drilled and extruded rivets.

34. Millivoltmeter Controllers

Minneapolis-Honeywell Regulator Co., Industrial Div.—Brown millivoltmeter described in 4-page illustrated bulletin 1060 is housed in 19-in. wide horizontal case suitable for mounting in standard relay racks. Controller is a three-zone control form that is adjustable from 0 to 100 or 0 to 10 per cent of the scale.

35. Meehanite Metal

Meehanite Metal Corp.—Design and engineering properties of various types of Meehanite castings available to industry are summarized on a wall chart. Data on general engineering, heat, wear and corrosion resisting types of metals are given. Graphs show effect of alloys influence upon strength properties.

36. Conveyor Belt Selectors

United States Rubber Co.—Two slide rules reduce time needed to design a conveyor installation from 3 hours to 10 minutes. One is devoted to selection of carcass, while the other calculates the horsepower required. Former covers number of plies for [illegible]

(Continued on Page 238)

1	23	45	67	89	111	133
2	24	46	68	90	112	134
3	25	47	69	91	113	135
4	26	48	70	92	114	136
5	27	49	71	93	115	137
6	28	50	72	94	116	138
7	29	51	73	95	117	139
8	30	52	74	96	118	140
9	31	53	75	97	119	141
10	32	54	76	98	120	142
11	33	55	77	99	121	143
12	34	56	78	100	122	144
13	35	57	79	101	123	145
14	36	58	80	102	124	146
15	37	59	81	103	125	147
16	38	60	82	104	126	148
17	39	61	83	105	127	149
18	40	62	84	106	128	150
19	41	63	85	107	129	151
20	42	64	86	108	130	152
21	43	65	87	109	131	153
22	44	66	88	110	132	154

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THE DIFFERENCE... *Carpenter* stainless uniformity

These hinge pivot pins for automatic dishwashers were being turned out by "doing things the hard way." Tools had to be reground every eight hours. The ordinary Type 303 steel used wasn't uniform, refused to hold size, and didn't provide the required finish.

This job could easily have been chalked up as a "necessary headache," but someone wasn't satisfied . . . was willing to explore the possibilities for improvement. As a result, Carpenter Stainless No. 8 (Type 303) has brought these worthwhile changes: Tool regrinding is required only every 18 to 24 hours . . . final grinding of the part is eliminated because size tolerances were held so accurately . . . bar after bar machines the same . . . and each part now costs 50% less.

Build your own improvement program with the cooperation of Carpenter . . . originator of the first Free-Machining Stainless. The steel can be in your plant almost immediately if you call your nearest Carpenter Mill-Branch Warehouse, Office or Distributor now. *The Carpenter Steel Co., 120 W. Bern St., Reading, Pa.*

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easier machining
fewer rejects
smoother finishes
lower production costs

Carpenter STEEL

Free-Machining Stainless Steels

IMMEDIATE DELIVERY from local warehouse stocks — Export Address: Port Washington, N. Y. — "CARSTEELCO"

Helpful Literature

(Continued from Page 218)

troughing and proper pulley diameters for entire system. Horsepower calculator is applicable to various types of conveyor systems.

37. Worm Gear Drives

Cleveland Worm & Gear Co.—Brief descriptions of Cleveland worm gear drives that have given good service for long periods of time are contained in 8-page illustrated booklet "Always on the Job." Various types are illustrated.

38. Printed Circuitry

National Vulcanized Fibre Co.—Reprinted 12-page illustrated bulletin "Mechanize Your Wiring With Copper-Clad Phenolite" covers the advantages of printed circuitry for electrical and electronic systems. Description of production methods is included. Specifications of various types and grades of copper-clad Phenolite base material are given.

39. Rotary Gear Pump

Sier-Bath Gear Pump Co.—Heavy duty Hydrex rotary gear pump for oils, burner service, hydraulic machinery, lube oil circulation and general transfer service is subject of 8-page illustrated folder. Operating range is 32 to 250,000 SSU, 1 to 350 gpm at 300 psi for continuous duty, and 500 psi intermittent duty.

40. Molded & Extruded Rubber

Tyer Rubber Co., Industrial Products Div.—Illustrations and descriptions of line of molded and extruded rubber products are found in engineering data book. Section is devoted to technical properties of natural rubber, Buna S, Buna N, neoprene, butyl, Thiokol and silicone. Products include seals, boots, gaskets, rolls, covers, sleeves, shields and shock mounts.

41. Teflon Stock & Fabricating

United States Gasket Co.—Chemical, electrical, thermal and mechanical properties of Teflon are covered in bulletin 300. Material is offered in sheets, tape, molded cylinders and bars, extruded tubing and rods, electrical spaghetti, beading and extruded shapes. Special molding techniques and bonding Teflon to other products are described. Custom molding, machining and fabricating is detailed.

42. Measurement & Control System

Weston Electrical Instrument Corp.—Technical and application data on the Inductronic system for measurement and control are found in catalog B-36-A. The basic direct current amplifying unit and multirange dc amplifiers, sensitizing amplifiers, integrating fluxmeters, limit and knife-edge control units and product resolvers are described.

43. Stainless Steel

Allegheny Ludlum Steel Corp.—"AM 350, A Chromium-Nickel-Molybdenum Stainless Steel, Hardenable by Subzero Cooling or Double Aging" is title and subject of illustrated 10-page booklet. It bridges gap between 300 and 400 series steels. Properties, corrosion rates and effects of cold rolling and aging on hardness and tensile properties are given.

44. Liquid Measuring Meters

Buffalo Meter Co.—Water, oil, hot water, chemical and other industrial liquids can be measured by Niagara meters described and illustrated in 20-page bulletin No. 36. Meter registers are available for continuous measurement, batch metering for manual or automatic control, rate-of-flow measurement and controlling proportional flow. Specifications for all types are presented.

45. Hardness Conversion Chart

Babcock & Wilcox Co.—Technical data card 183 charts approximate relation between hardness by various testing systems and tensile strength of carbon and alloy steels.

46. Time Totalizers

R. W. Cramer Co.—Time totalizers are subject of 8-page bulletin PB-610 which provides time ranges, housing information, dimensions and wiring diagrams. Units covered are type 690 electrical stop clock for use in nuclear research, laboratory testing and for checking communications equipment and systems. Type 650 and 640 running time meters are also covered.

47. Four-Way Valves

Denison Engineering Co.—12-page illustrated bulletin VD-7 presents technical data on ⅛-in. solenoid operated and ¾-in. pilot operated four-way valves for 3000-psi systems. Four spool types are offered. Bulletin contains complete specifications and engineering drawings for various models.

48. Special Connectors

DuJur-AMSCO Corp.—Several special-design connectors now available at low prices are described in two data sheets. Included are molded types with die cast brackets, precision miniature connectors, hermetic seal plugs, a hermetic receptacle with 90-degree cable plug and a special connector for printed circuits.

49. Variable Speed AC Motors

Bugas Electric Mfg. Co.—N-8 variable speed alternating current motors for stepless control of machine tools, mills, conveyors and processing machines are described in 8-page NB-100. Available sizes range from ½ to 1250 hp with speed ranges from 30:1 to 1.5:1.

50. Two-Way Midget Valves

Automatic Switch Co.—Technical data form V5081 on bulletin S262 two-way midget packless valves is supplement to catalog listed valves. Valves are made in new port and pipe sizes up to ⅛ in.; are rated up to 250 psi air; and have new UL approval and listing. Explosionproof valves are made for air, water, light oil and noncorrosive gas and liquid service.

51. Stainless Steel Design

H. K. Porter Co., Alloy Metal Wire Div.—40-page "Design Handbook" covers in detail properties, specifications, applications and design data on 20 grades of stainless steel wire, rod and strip. Chapters deal with selection of stainless steels for corrosion resistance, heat resistance, mechanical properties and spring properties.

52. Air & Hydraulic Cylinders

Logansport Machine Co.—Logansquare cylinders for air or oil service are described as to dimensions and mountings in 16-page catalog 100. Cylinders are offered in eight bore sizes from 1½ to 8 in. They work on up to 150 psi air; 500 psi oil. Applications include pushing, lifting, holding, pulling, tilting, clamping, pressing, turning, squeezing and other power movements in any direction.

53. Direct Current Motors

Reliance Electric & Engineering Co.—Dynamic response, or the controlled reaction of motors to the demand for a change, is featured by Super T line of direct current motors described in 12-page bulletin C-2002. Units range from 7½ to 250 hp at up to 1750 rpm and are used to drive presses, conveyors, shears, machine tools and processing lines.

54. Electric Gearmotors

Marathon Electric Mfg. Corp.—Large cutaway illustration in 4-page bulletin SB-151 points out 10 individual features of AGMA class 1, 2 and 3 double reduction electric gearmotors. These features cover units rated 1 hp and up. Single and triple reduction units are covered briefly as well.

55. Fire-Resistant Fluid

Monsanto Chemical Co.—Pydraul F-9 fire-resistant fluid for hydraulic equipment operating near possible sources of ignition is subject of 20-page descriptive brochure. Fluid equals premium grade petroleum fluids in lubricity, stability and service life, yet is water-free, noncorrosive and safe to use.

56. Arc-Cast Molybdenum

Climax Molybdenum Co.—Compilation of all available technical and fabricating data on arc-cast molybdenum is presented in 72-page booklet "Arc-Cast Molybdenum and Its Alloys." Booklet presents a complete picture of where molybdenum stands today in terms of high temperature applications and its possible uses in the near future. Other uses for which this material has been proposed are covered as well.

57. Steel Selection Guide

Carpenter Steel Co.—32-page guide to specialty steels defines the distinctive characteristics of broad range of special purpose steels in terms of end use. It covers tool and die steels; stainless steels; silicon and low nickel electrical alloys; special purpose alloy steels; and valve, heat-resisting and super alloy steels, tubing and pipe in various alloyses and fine wire specialties.

58. Automatic Control

U. S. Electrical Motors Inc.—Any process requiring automatic variable speeds can be driven by the U. S. Varidrive with Varitrol control, described and illustrated in 8-page form F-1882. Speeds are automatically changed in response to a signal without human attention. Typical Varidrive applications are shown and the Varitrol system function is explained.

59. Set Screws

Set Screw & Mfg. Co.—List prices and dimensional information on set screws is offered by 24-page catalog No. 19. Covered are socket, cup, slotted, fluted socket, off-set, as well as pipe plugs, hexagon keys and special self-locking and slabbed head set screws, as products. Thread and weight data are provided along with decimal equivalents charts.

60. Fluid Power Devices

Modernair Corp.—Full-line '54-'55 catalog is a presentation of Modernair air and hydraulic cylinders, valves and packaged units. It contains easy-to-use dimensional drawings, installation, operating and technical data on company's products; and up-to-date price lists.

61. Variable Speed Drives

Sterling Electric Motors, Inc.—Speed-Trol variable speed transmissions are described in 8-page bulletin 188 which features the inner workings of the Sterling positive pulley design. Information on factors in drive selection and a description of the many types of automatic and remote speed control accessories available are included.

62. Fluid Pressure Boosters

Miller Fluid Power Co.—Available literature includes 4-page bulletin on fluid pressure reciprocating boosters. Mounting and dimensional data cover units in 4, 5, 6, 8, 10, 12 and 14-in. bores in 1 through 5½-in. diameter rams. Supplementary 12-page pamphlet "J.I.C. Pneumatic Standards for Industrial Equipment" has cut-away illustration of the 200-psi air cylinder.

63. Electric Clutches

Warner Electric Brake & Clutch Co.—Unique ball-cam principle of MDO (multiple-disk, oil) electric clutches allows fast engagement and release, and high "modulated" torque in enclosed machine drives and transmissions. 6-page bulletin WEB 6198 describes how MDO clutches work. Torque ratings range from 52 to 788 lb ft.

64. Electrical Devices

Trico Fuse Mfg. Co.—Electrical and lubricating devices described in 8-page catalog 55 are fuses, fuse pullers, fuse reducers, test and fuse clip clamps and automatic oilers. Size, general engineering and ordering data are given.

65. Polyester Resins

Allied Chemical & Dye Corp., Barrett Div.—Data folder contains series of technical bulletins on line of rigid, flexible and resilient Plaskon polyester resins. When reinforced with fiber glass, resins form high strength laminates which are used in wide variety of applications such as car and truck bodies, luggage, corrugated panels and boat hulls.

Closeup of mandrel, Ampco-coated steel balls fill tube during bending, prevent walls from collapsing.

Completed bend in Pines Precision Bending Machine.

Pines Engineering
licks "impossible" job

... bends ultra-thin stainless tubing

... cuts airplane costs $14,000

***thanks to* AMPCO* METAL**

AIRCRAFT engineers said that cold bending of thin-wall tubing sections for engine and airframe components was impossible — that it couldn't be done. But Pines Engineering Co., Aurora, Illinois, went to work anyway. It developed a precision bending machine that makes smooth, sharp bends to 10" centerline radius in up to 5" diameter x .025" wall stainless tubing — bends that are cutting airplane costs up to $14,000 each.

Pines selected Ampco Grade 20 wiper dies and Ampco-coated mandrels for their new precision machine to resist the tremendous pressures developed in this bending operation. Here's what they say:

"Ampco eliminates the problem of pickup on the mandrel and wiper die when bending stainless steel tubing. And Ampco provides a hard-wearing surface that enables the production of thousands of bends before dies have to be refitted."

And if you draw, form, or bend stainless, pickled carbon steel — or many other metals — here's what *you* get with Ampco dies:

Little or no pickup. You eliminate all the expense of redressing steel dies — redressing that is necessary because of scratching, galling, or pickup. Idle time is cut — and your line keeps moving at top production.

Low finishing costs. You end galling, loading, scratching, die marks. No more problems with big scrap losses. You reduce expensive finishing time.

This remarkable copper-base alloy pays off on your drawing or forming line with longer life, lower costs, less operating grief. Get all the facts on cost-saving Ampco dies from your nearby Ampco field engineer or mail the coupon.

Tear out this coupon and Mail Today!

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NEW PARTS AND MATERIALS

For additional information on these new developments, see Page 217

Miniature Nuts 66

are self-locking

Line of one-piece Flexloc micro nuts, miniature self-locking fasteners for precision instrument fastening applications, includes nine sizes from 0-80 up to 4-48. Smallest nut measures less than ⅛-in. across. These all-metal fasteners function as stop nuts as well as locknuts. Spring-like pressure of resilient, slotted collar segments holds nut securely in place, whether seated or not. Micro nuts are available in either plain

or cadmium-plated brass, or aluminum. Made by **Standard Pressed Steel Co.**, Stewart Ave., Jenkintown, Pa.

Circle No. 66, Page 217, for more data

Variable-Speed Pulley 67

for limited space applications

Speed ratios up to 2:1 are obtained with the E-1350 variable speed pulley, a ¼-hp unit for limited space applications. It can be mounted with the belt take-off close to the motor, or it can be reversed with the belt take-off in an overhung position. The pulley uses an A-section belt and has a maximum bore of ⅝-in. with keyway.

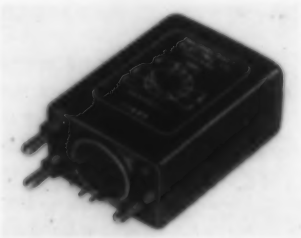
Bronze oil-impregnated bearings eliminate the need for lubrication in most applications, but where lubrication is required, the pulley can be equipped with a pressure grease fitting. The pulley is 3 5/16 in. long and 3 in. in diameter. It can be used with various sliding bases or shifting mechanisms. Made by **Lovejoy Flexible Coupling Co.**, 4818 W. Lake St., Chicago 44, Ill.

Circle No. 67, Page 217, for more data

Rectified Relays 68

convert ac to dc for sensitive operation

Full-wave rectifiers incorporated in these relays convert alternating current to rectified direct current,



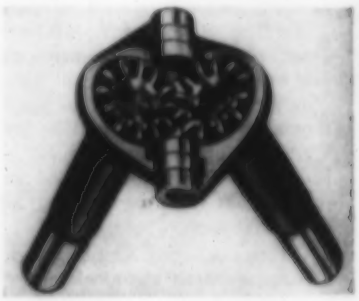
thus providing dc operation from ac supply. Direct-current operation provides high operating sensitivity, high contact pressures, great resistance to vibration, reliable operation through range from 25 to 400 cycles ac, freedom from hum and reduced size. Relays are offered with a wide range of contact combinations in hermetically sealed or dustproof enclosures, as well as open types. Made by **Magnecraft Electric Co.**, 3350T W. Grand Ave., Chicago 51, Ill.

Circle No. 68, Page 217, for more data

Hinged Gear Joint 69

transmits power at any point within 137-deg arc

Automation and remote control of machine tools, processing equipment and laboratory test devices



are some of the uses for this hinged gear joint. It will carry shaft-transmitted power around corners at angles from 3 to 140 deg away from a straight line. Teeth of the bevel gears mesh smoothly at any angle within the arc. Four teeth are engaged when the joint is in the fully opened position. Available for 7/16, ½ and 9/16-in. shaft sizes, it is 10½ in. long. Housing is a drop-forged and heat-treated section made in two parts. The joint is also usable

lubricating "brains" built into any machine!

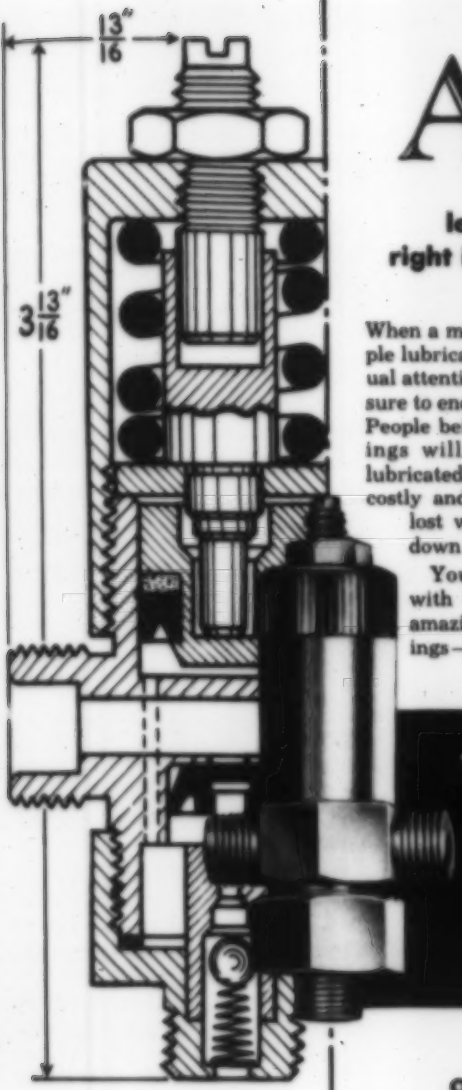
ALEMITE Accumatic®

lets you design automatic, fool-proof lubrication right into any machine — simply, economically . . . offers the operating savings industry will buy!

When a machine is designed with multiple lubrication fittings that require manual attention, the user of that machine is sure to encounter a number of problems. People being what they are, some bearings will be neglected, others over-lubricated. Further, hand lubrication is costly and valuable production time is lost when machines must be shut-down for lubrication.

You avoid all of these troubles with the Alemite Accumatic. This amazing valve fits directly on bearings—meters an exact shot of oil or grease *automatically—at pre-determined intervals—while the machine is in operation!* Time, production and maintenance costs are cut to the bone! With all these advantages, it is small wonder that 95% of all major plants buying machine tools specify centralized lubrication.

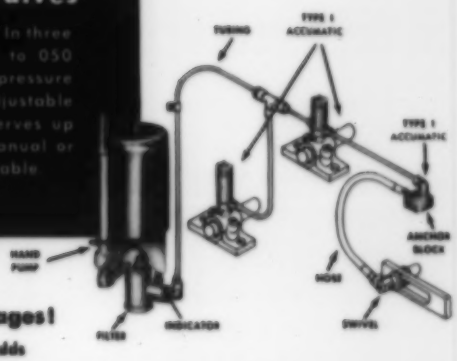
The Alemite Accumatic system is simple to design and build into any machine. Automatic Accumatic Systems assure you positive, low-cost lubrication. Find out about these automatic systems now. See the savings, the efficiency they add and you too will specify Accumatic!



Adjustable Output/Cap.

Type 1 Accumatic Valves

For fluid oil or light grease. In three sizes, delivering from .005 to .050 cu. in. of lubricant. Spring pressure provides gradual feed. Adjustable or fixed output. System serves up to 400 bearings. Either manual or automatic operation available.



Offers All These Advantages!

- **Eliminates shut-down time for lubrication. Adds productive time to machine output.**
- **Seals completely against dirt, grit, water all the way from "Barrel-to-bearing."**
- **Prevents bearing troubles due to neglect or use of wrong lubricant.**
- **Services all bearings — including those inaccessible or dangerous — in one operation.**
- **Avoids work spoilage and bearing repairs due to over-lubrication.**

Factory-tested—field proved

Exhaustive, in-the-field tests show no appreciable variation in the amount of lubricant discharged after 73,312 lubrication cycles—equal to 122 YEARS of *twice-a-day service!*

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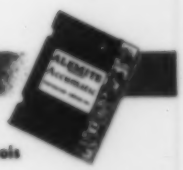

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for out-of-line power transmissions up to ¼-hp at speeds to 1750 rpm. Made by **Gray & Prior Machine Co.**, 614 Windsor St., Hartford, Conn.

Circle No. 69, Page 217, for more data

Ball Bearings 70

installed in minimum time

Available for shaft diameters up to ½-in., this line of semiprecision ball bearings is designed for installation in minimum time. Standard and sealed models are available. Bearings have precision ground balls and case hardened races to withstand heavy radial loads in general purpose, low-

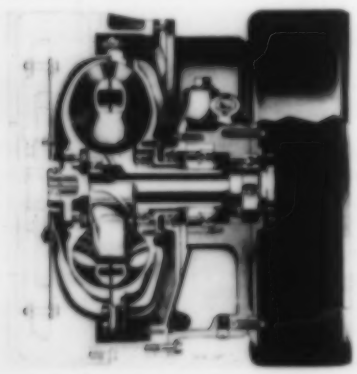
speed applications. Made by **Freeway Washer & Stamping Co.**, 4911 Grant Ave., Cleveland 5, O.

Circle No. 70, Page 217, for more data

Torque Converter Couplings 71

rated at 280 lb-ft

Basic elements of each of three new torque converter couplings are an impeller or pump, runner, and reaction member. With single-stage, two-phase design, the reaction member is mounted on an overrunning clutch which permits rotation with the runner and op-



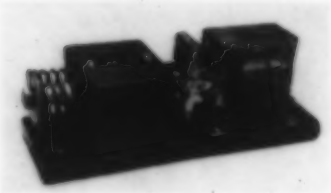
eration as a straight hydraulic coupling for high efficiency. The change from 2.1:1 conversion stage operation to straight hydraulic coupling stage and back is automatic, depending only upon the amount of torque required in the drive line. Torque rating is 280 lb-ft. Coupling shown incorporates an SAE No. 3 clutch housing behind the converter. The output shaft is flanged for attachment of a single-plate clutch flywheel. Two other models are made without clutch housings. One offers a flanged output shaft for attachment of industrial type couplings and the other has a 1¼-in., ten-spline shaft on the output end for straight-line drives through a universal joint. Made by **Fuller Mfg. Co.**, Kalamazoo, Mich.

Circle No. 71, Page 217, for more data

Control Valves 72

constructed primarily of plastic materials

Valves suitable for use with air, oil and many other fluids at pressures up to 200 psi and temperatures to 200 F are long wearing

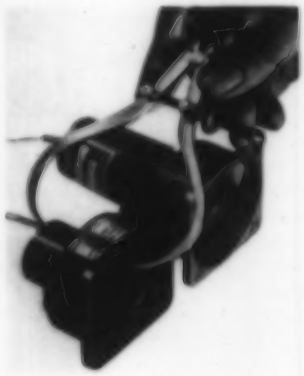


and highly resistant to abrasive and corrosive conditions. The radially serrated plunger is hard coated aluminum, and the one-piece body is machined from canvas-base phenolic laminate. It has annular grooves and Neoprene O-ring seals. A phenolic plunger is available for special applications. Valves are made in two basic body types. The three-port model includes two, three and four-way open exhaust. The solenoid valve illustrated is a three-port model. Two and five-port models are also available. Double solenoid actuation can be specified in either five or three-port designs. Solenoids have solder lugs, are rated for constant duty and can operate at the rate of 200 cycles per minute. Both 110 and 220-v solenoids are available. The valves are generally large enough for cylinders up to 5-in. bore. For fluid control they provide a ¼-in. orifice, and are furnished with springs if required. Made by **John D. Bachman & Co.**, Bristol, Tenn.

Circle No. 72, Page 217, for more data

Miniature Axial Blowers 73

for either ac or dc power



Axial blowers for operation on either ac or dc are available with air flow in either direction. The ac blowers combine a Globe type SC 400 or 60-cycle motor and a die-cast aluminum fan mounted in a die-cast aluminum housing. The dc blower uses a type SS motor and can be furnished with standard windings. It can be made to meet the radio noise requirements of MIL-I-6181 specifications. Blowers are available for operation on frequencies other than 400 cycles per second. They operate at speeds which deliver air at rates up to 50 cfm. Made by **Globe Industries Inc.**, 1784 Stanley Ave., Dayton 4, O.

Circle No. 73, Page 217, for more data

Time Delay Relay 74

has 0.25-per cent accuracy

Type 412, synchronous motor driven, time delay relay has setting mechanism that is adjustable over the full dial range, even while the timer is operating. Two pointers indicate time setting and progress. Operation is from either a momentary or sustained closure. Two single-pole double-throw and one single-pole single-throw heavy

duty open-blade contacts provide positive quick-make, quick-break operation. Many external load connection arrangements are possible without changing internal wiring. Contacts are rated 15 amp at 125 v ac. Repeat accuracy is within ±0.25-per cent of full scale on times over 30 seconds. Fourteen ranges from 6 seconds through 24 hours are offered for use on 115 and 220 v, 25, 50 and 60 cycles. Made by **R. W. Cramer Co.**, Centerbrook 5, Conn.

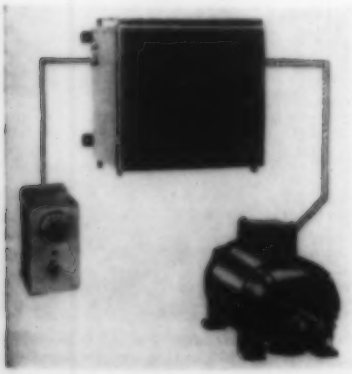
Circle No. 74, Page 217, for more data

Adjustable-Speed Drive 75

has high speed stability

Series 100 adjustable-speed drives permit a precise adjustment of speed over a 100:1 speed range. Speed variation is less than 0.5-per cent of full rated speed, despite wide changes in line voltage, temperature or torque load. Both ¼ and ½-hp models are available, either of which is adjustable for operation at speeds between 36 and 3600 rpm. Drive motors operate at less than the NEMA-recommended maximum temperature rise. A concrete-like epoxy resin encapsulates all resistors and capacitors within easily removed plug-in assemblies. Any part can be replaced quickly using only a screwdriver. A compact control head utilizes only low-voltage circuits that can be installed at a point remote from either the rectifier cabinet or the motor. The cabinet can be either wall or bench-mounted. It is chromate treated to prevent corrosion and finished in a baked green enamel. Made by **Servo-Tek Products Co. Inc.**, 1086 Goffle Rd., Hawthorne, N. J.

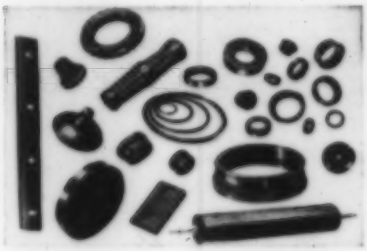
Circle No. 75, Page 217, for more data



Molded Rubber Parts 76

made to specifications

Rubber parts molded to specifications, as well as standard parts, are available in either natural rubber, Neoprene, Buna N, Buna S



GRS, Butyl, or Silastic silicone rubber. Typical parts are air brake diaphragms, bumpers and snubbers, wheels, gaskets, spring inserts, oil seals, O-rings, rubber covered rolls and idlers, regulator diaphragms and radio and television parts. Made by **Quality Rubber and Transmission Co.**, Dept. MDC, 2203 W. Chicago Ave., Chicago 22, Ill.

Circle No. 76, Page 217, for more data

Laminated Plastic 77

for low-temperature punching

Grade XXXP-470 Phenolite, an electrical grade phenolic laminated plastic, can be punched at temperatures as low as 68 F. It is suitable for copper clad printed circuits where automatic processes require close registration of punched mounting holes for component inserts. Properties of high insulation resistance and low electrical losses, even under severe humidity conditions, match or ex-

(*Continued on Page* 230)

New manufacturing process improves performance of CHROMALOX Electric Strip Heaters

An improved manufacturing process, combined with a newly developed refractory material, offers you the finest performance in strip heaters. Rugged and long lasting, they are industry's workhorse among heating elements.

So when you use the improved line of Chromalox Electric Strip Heaters, you're assured of even better performance in the heating of platens, dies, kettles, tanks, ovens, air ducts and other applications that require dependable, accurately controlled heat . . . where and when heat is needed.

Let the Chromalox Sales-Engineering staff solve your heating problems—electrically.

Write for your copy of Catalog 50

This data-packed catalog covers the design, uses and prices of the complete line of Chromalox Electric heaters, elements, thermostats, contactors and switches.

To get short factual material on many additional applications of electric heat, send for Booklet F1550 "101 Ways to Apply Electric Heat."

Edwin L. Wiegand Company

7575 Thomas Boulevard, Pittsburgh 8, Pa.

EDWIN L. WIEGAND COMPANY
7575 Thomas Boulevard, Pittsburgh 8, Pa.
I would like to have—
☐ a copy of Catalog 50
☐ a copy of "101 Ways"
☐ a Sales Engineer contact me
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Company
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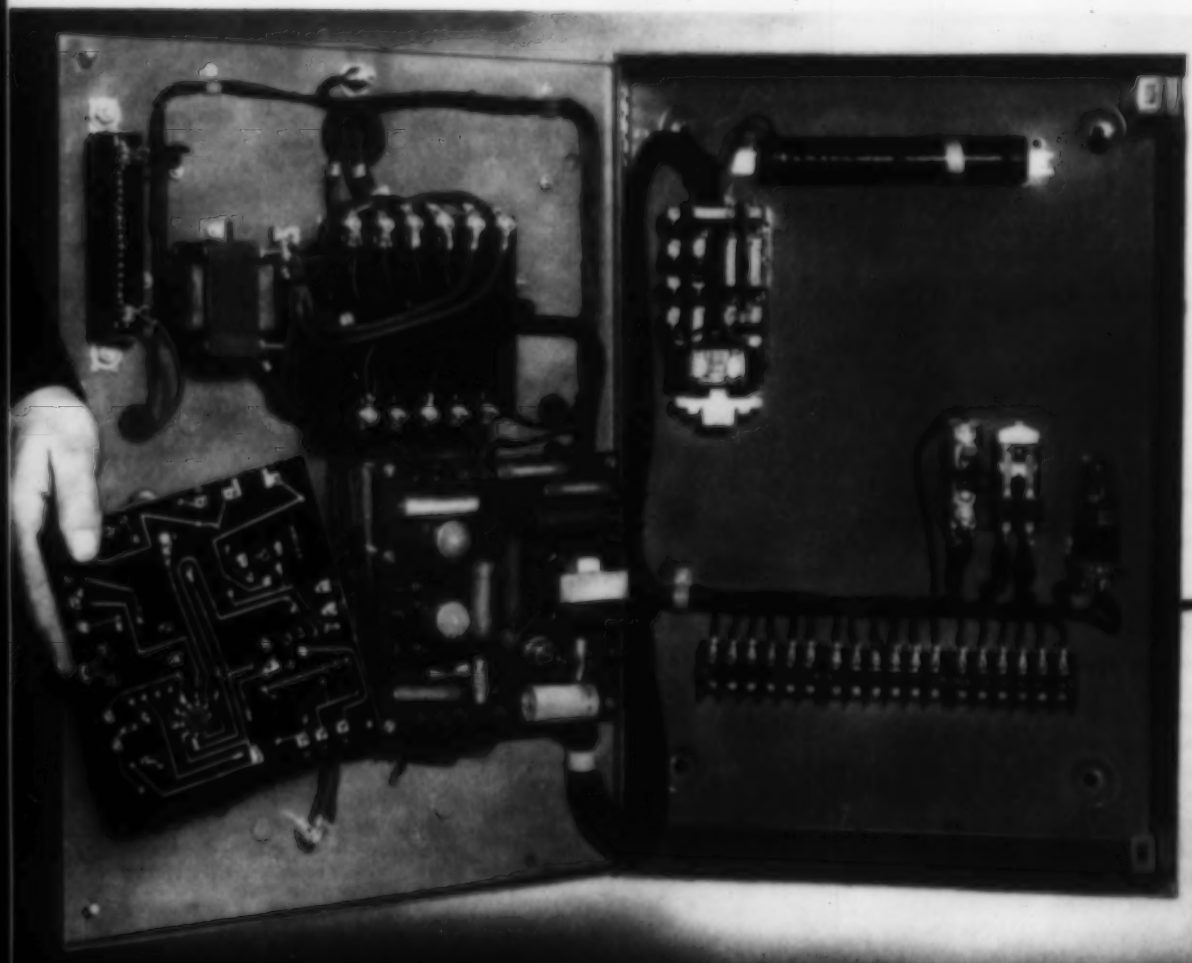
ERIE COUNTY PUBLIC LIBRARY

GENERAL ELECTRIC ANNOUNCES ADDITION TO THY-MO-TRO

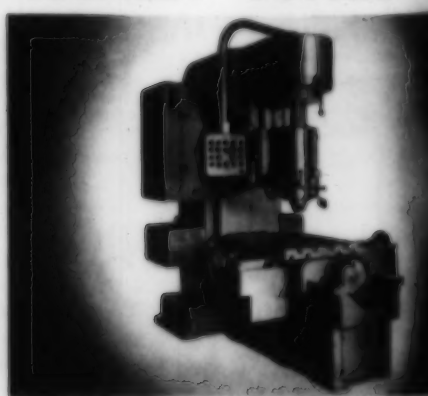
NEW Low-priced 3/4-3 HP



G-E THY-MO-TROL DRIVES ARE IDEALLY SUITED

Electronic Induction Heater. Thy-mo-trol Drive moves the carriage to exact pre-set conditions to assure uniform heat treatment.

Surface Grinder. All motions on this grinding machine are controlled by General Electric's Thy-mo-trol Drive: spindle, table and cross-feed operations.



Milling Machine. Thy-mo-trol Drives automatically step up production on this milling machine by giving correct speeds for spindle, table and spindle head drive requirements.

DRIVE LINE . . .

Thy-Mo-Trol Drive with Printed Circuitry

NOW! FOR MACHINE TOOL APPLICATIONS —A RELIABLE, SIMPLIFIED, ADJUSTABLE SPEED DRIVE

These new, simplified General Purpose, 3/4-3 HP Thy-mo-trol Drives have been developed for industrial applications demanding wide speed range and close speed regulation. Embodying all the smooth adjustable speed characteristics of DC drives, the two models offer greater performance, reliable operation and wide speed range selection for many industrial applications.

A PRICE REDUCTION, due largely to G.E.'s industrial application of printed circuitry has been made. The entire control system has been simplified, giving the user substantial reductions in over-all weight, size, circuit complexity, amount of wiring, maintenance costs and installation costs.

OPERATING DIRECTLY FROM AC POWER, the new Thy-mo-trol Drives can increase machine production on most applications because they • Give the correct speed for the required operation • Reduce operating spoilage and rejects because of high accuracy performance and • Increase machine versatility because of the wide speed range and close speed regulation features offered.

THE COMPLETE THY-MO-TROL DRIVE LINE COVERS ratings from 1/40 to 30 HP and beyond. Speed ranges of 5:1, 20:1, 50:1, and 100:1 are typical. Speed regulation of ½ of 1% is possible over the entire speed range.

SIMPLIFIED FRACTIONAL HORSEPOWER THY-MO-TROL DRIVES are supplied as half-wave or full-wave units, allowing a wide selection of performance standards to meet each particular industrial application.

HIGH PERFORMANCE INTEGRAL HP THY-MO-TROL DRIVES, 3/4-30 HP, full-wave offer these superior performance features: greater flexibility, rugged industrial-type construction, easy maintenance, wide speed range, adjustable current limit, flat speed regulation and optional features such as: jogging, quick slowdown, reversing, dynamic braking, tachometer feedback and position synchronization all add up to qualify these drives for many machine tool and industrial applications.

FOR MORE INFORMATION on General Electric's Thy-mo-trol electronic adjustable speed drives, contact your nearest G-E Apparatus Sales Office or write for Bulletins GEA-6234, GEA-4089, GEA-5179, GEA-5827 and GEA-5337—General Electric Company, Schenectady, N. Y. 791-2

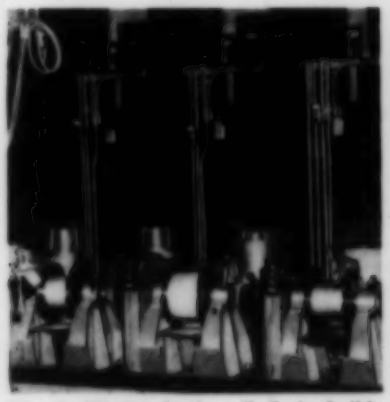
Progress Is Our Most Important Product

GENERAL ELECTRIC

® Reg. Trade-mark of General Electric Company.

TO THESE TYPICAL INDUSTRIAL APPLICATIONS

Cookie Conveyor. Repeated variations in speed—necessary to meet baking requirements—are easily handled by Thy-mo-trol Drive.

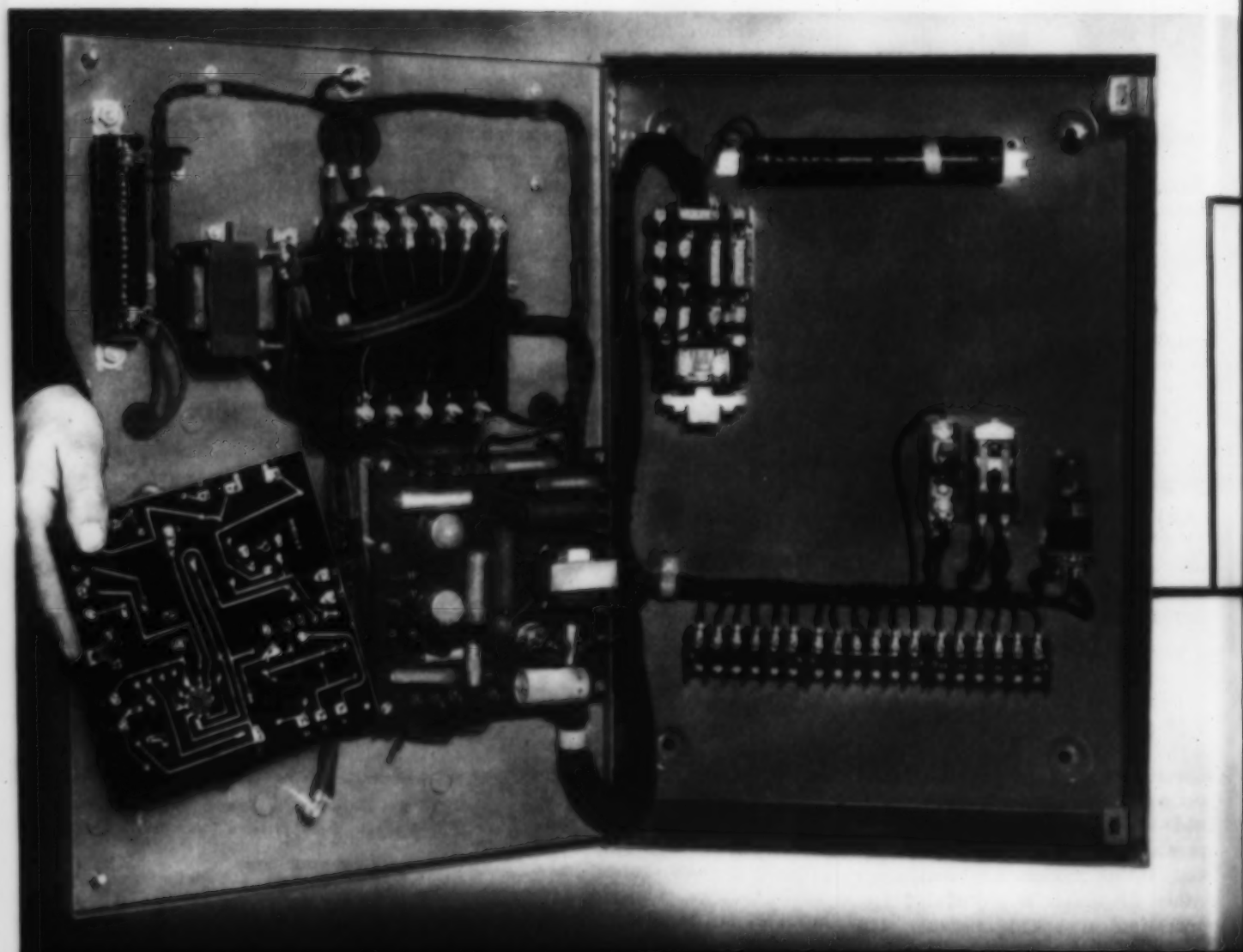


Wire Re-Winder. As the coil of wire builds up, Thy-mo-trol Drive continually adjusts speed of reel to maintain constant winding at maximum speed.

Tire-Treading Machine. A continuous strip of tire-tread passes from extruder (in background) to conveyor. Thy-mo-trol Drive synchronizes the operation.

GENERAL ELECTRIC ANNOUNCES ADDITION TO THY-MO-TROL*

NEW Low-priced 3/4-3 HP



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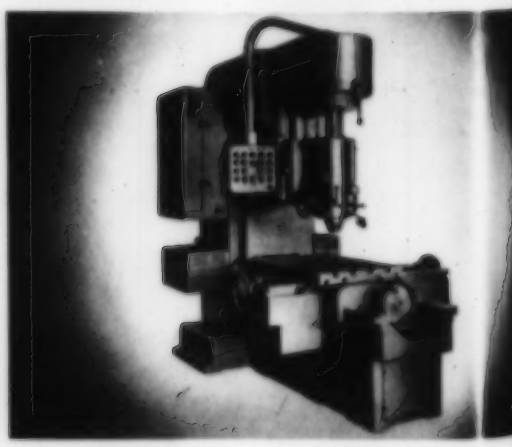

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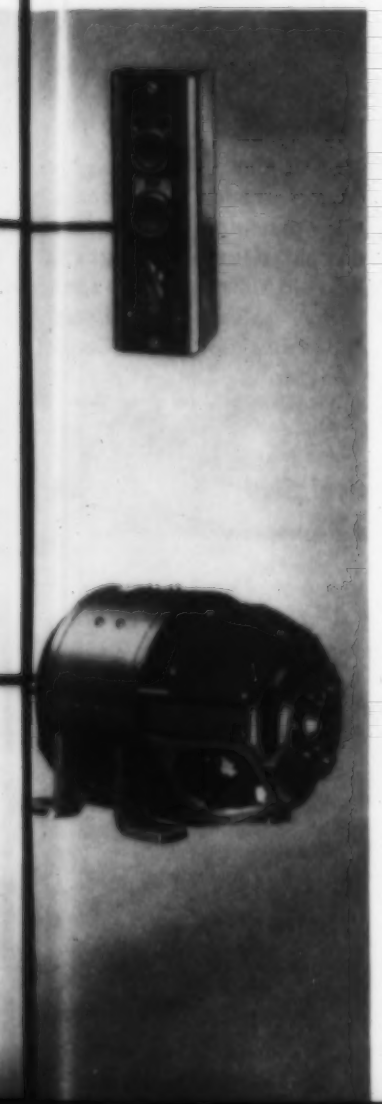

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Progress Is Our Most Important Product

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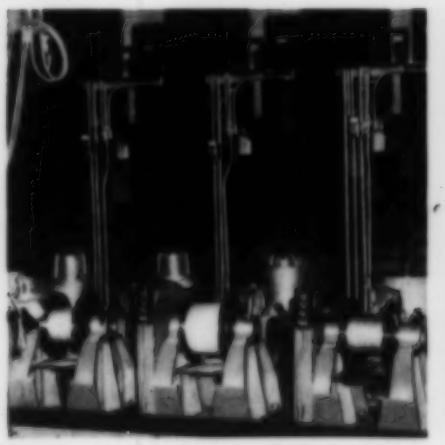

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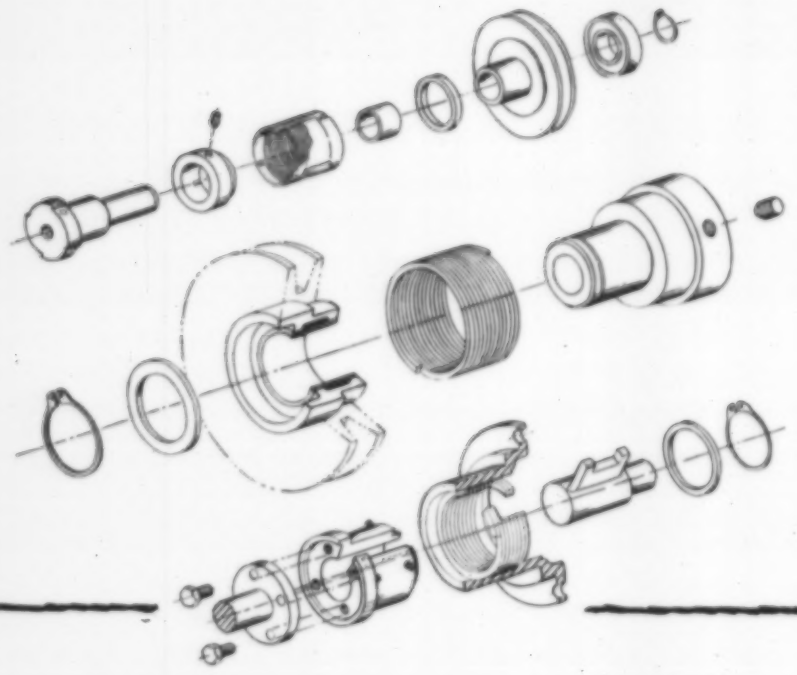
Tire-Treading Machine. A continuous strip of tire-tread passes from extruder (in background) to conveyor. Thy-mo-trol Drive synchronizes the operation.

When you need a clutch...



check into the many advantages of Marquette SPRING CLUTCHES

OVER-RUNNING or FREE-WHEELING CLUTCHES • INDEXING CLUTCHES
BI-DIRECTIONAL NO-BACK BRAKES • REVERSING CLUTCHES
SINGLE REVOLUTION CLUTCHES • DELAYED ACTION CLUTCHES

LOW COST • COMPACT • TROUBLE-FREE

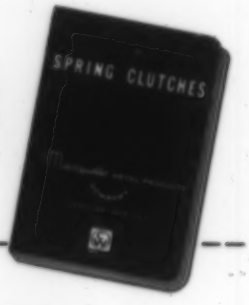
Marquette Spring Clutches have given dependable service for many years in a wide range of applications—from Aircraft to X-ray. They require very little space. They maintain their efficiency almost indefinitely. And they cost much less than other types of clutches.

Send today for your copy of illustrated manual that gives helpful data on Marquette Spring Clutches!

The Marquette
METAL PRODUCTS CO.
SUBSIDIARY OF CURTISS-WRIGHT CORPORATION

ALSO MANUFACTURERS OF: ROLLER BEARING TEXTILE SPINDLES
HYDRAULIC GOVERNORS • PRECISION PARTS AND ASSEMBLIES
AIRCRAFT WINDSHIELD WIPERS • FUEL OIL PUMPS & INJECTORS
ROTARY HIGH PRESSURE OIL FIELD PUMPING MACHINERY

A PRODUCT OF CW CURTISS-WRIGHT



THE MARQUETTE METAL PRODUCTS CO.
1141 Galewood Drive, Cleveland 10, Ohio

Please send manual describing the functions, applications and operations of the basic types of Spring Clutches.

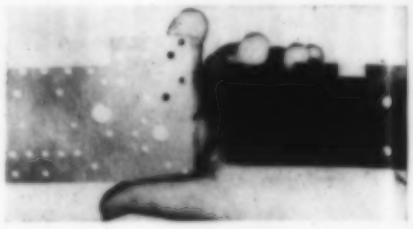
COMPANY _____

NAME _____ TITLE _____

ADDRESS _____

New Parts

(*Continued from Page 227*)



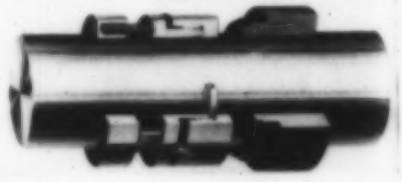
ceed values of these properties for hot punching grades of laminate. Good cold punching characteristics mean that flexural strength is lower and cold flow is higher than other grades. Made by **National Vulcanized Fibre Co.**, 1055 Beech St., Wilmington 99, Del.

Circle No. 77, Page 217, for more data

Mechanical Seal 78

for high-temperature service

Easily installed Dura rotary mechanical seal will handle hot oils or hot water at temperatures up to 800 F. Type RHU unbalanced assembly (illustrated) and type PHU balanced assembly are available. The seal is constructed generally of stainless steel and has



durable wearing faces and stainless steel U-ring shaft packings. Design allows for thermal expansion and does not require stuffing box flushing, unless to control vapor pressures or flush out excessive coke formation. Made by **Durametallic Corp.**, 2104 Factory St., Kalamazoo, Mich.

Circle No. 78, Page 217, for more data

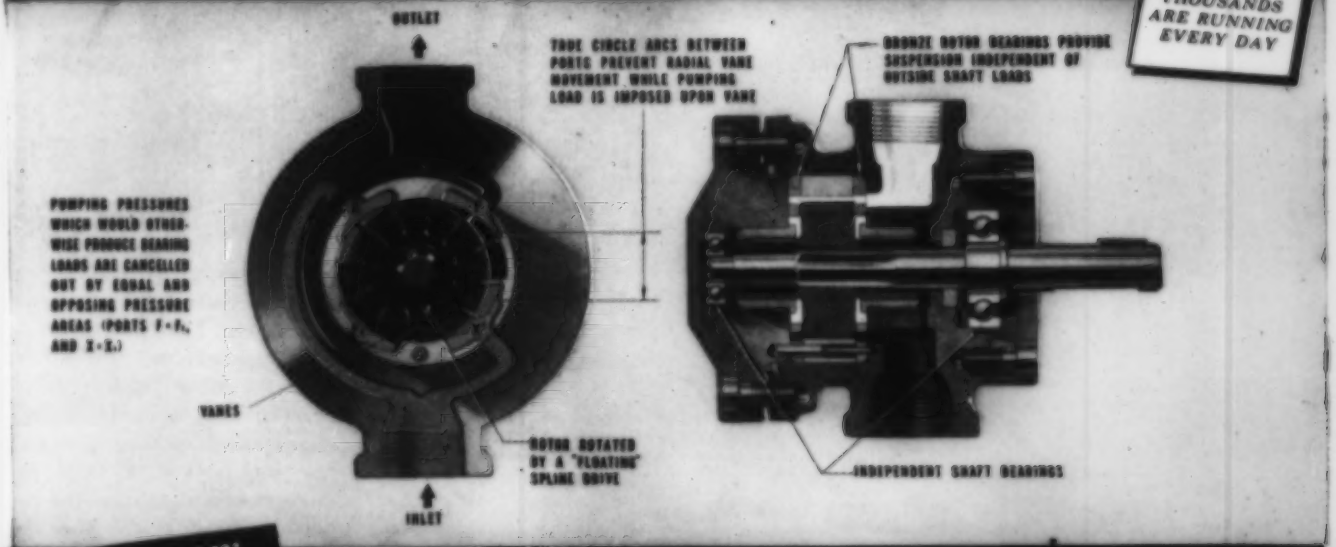
Rerated Motors 79

have slotted stators for good ventilation

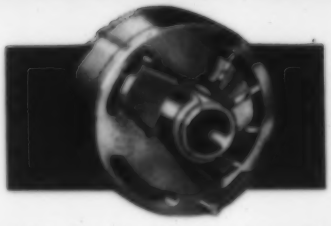
Series 100 motors utilize the NEMA-rerated frame sizes and incorporate a new stator ventilating system. The stator is made with wide ventilation slots in its outer periphery. Dividing fins, fitted against the motor frame, provide air passages for the free move-

Question: Why are VICKERS Balanced Vane Type Pumps the most widely used oil hydraulic power pumps?

HUNDREDS OF THOUSANDS ARE RUNNING EVERY DAY


OUTLET
TRUE CIRCLE ARCS BETWEEN PORTS PREVENT RADIAL VANE MOVEMENT WHILE PUMPING LOAD IS IMPOSED UPON VANE
BRONZE ROTOR BEARINGS PROVIDE SUSPENSION INDEPENDENT OF OUTSIDE SHAFT LOADS
PUMPING PRESSURES WHICH WOULD OTHERWISE PRODUCE BEARING LOADS ARE CANCELLED OUT BY EQUAL AND OPPOSING PRESSURE AREAS (PORTS 1-1, AND 2-2.)
VANES
ROTOR ROTATED BY A "FLOATING" SPLINE DRIVE
INDEPENDENT SHAFT BEARINGS
INLET

Answer: Because of their SUPERIOR PERFORMANCE and MANY OTHER BENEFITS for the user.



For more than two decades, the Vickers Balanced Vane Type has held the leading position among hydraulic power pumps . . . growing steadily in popularity. The various models (see below) are *the most widely used of all pumps in oil hydraulic service.*

Above is the pumping cartridge which is one of this pump's distinctive features. The many advantages listed at the right merit the thoughtful attention of anyone concerned with the selection and use of oil hydraulic pumps.

VICKERS INCORPORATED

DIVISION OF SPERRY RAND CORPORATION

1430 OAKMAN BLVD. • DETROIT 32, MICH.

Application Engineering Offices • ATLANTA • CHICAGO CINCINNATI • CLEVELAND • DETROIT • HOUSTON LOS ANGELES AREA (El Segundo) • MINNEAPOLIS NEW YORK AREA (Summit, N. J.) • PHILADELPHIA AREA (Media) • PITTSBURGH AREA (Mt. Lebanon) PORTLAND, ORE. • ROCHESTER • ROCKFORD • SAN FRANCISCO AREA (Berkeley) • SEATTLE • ST. LOUIS TULSA • WASHINGTON • WORCESTER

IN CANADA: Vickers-Sperry of Canada, Ltd., Toronto

COMPLETE HYDRAULIC BALANCE—Each inlet and outlet port is balanced by another equal in size and radially opposite . . . pressure-induced bearing loads are thus eliminated. Pressure-balanced porting plates maintain ideal running clearances.

FLOATING SPLINE DRIVE—Rotor is driven by a "floating" spline. Rotor and shaft have separate bearings . . . avoiding strain from drive misalignment.

TRUE-CIRCLE CAM ARCS between ports prevent radial vane movement while pumping load is imposed upon vanes. Wear between vanes and rotor is thus practically eliminated.

ABILITY TO TOLERATE DIRT—Clean oil is of great importance in a hydraulic circuit; but, in spite of care, dirt sometimes gets in. The Vickers Vane Type Pump will pass a reasonable amount of dirt without trouble and without grinding it up.

REPLACEABLE CARTRIDGE—Cartridge (illustrated above left) contains all pumping parts that move . . . none contact the housing. Working parts can be removed and inspected without disconnecting piping or drive coupling. Replacement cartridge kits are available and pumps need not be sent to the factory for repairs. Pump capacity can be changed by simply changing cartridge in the field.

HIGHER EFFICIENCY—Tests prove exceptionally high volumetric and overall efficiency . . . not only when pump is new but also after long service.

AUTOMATIC WEAR COMPENSATION—Vanes are held in contact with the cam ring by centrifugal force and hydraulic pressure. If wear occurs, vanes revolve in a slightly larger orbit without appreciable change in performance.

MINIMUM MAINTENANCE—Hydraulic balance . . . floating spline drive . . . independent bearings . . . automatic wear compensation eliminate the most important causes for maintenance and repair.

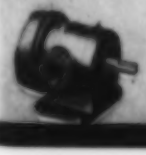
TEMPERATURE ADAPTABILITY—Correct running clearances are automatically maintained which compensate for wide variation in oil viscosity resulting from temperature variation.

LONGER LIFE—The numerous features mentioned above that keep down maintenance also contribute to longer life. Then, a new cartridge completely rejuvenates the pump.

CONSTRUCTION SIMPLICITY is evident from the illustrations above. This simplicity is another reason for the superiority of Vickers Vane Pumps. For further information, ask for Bulletin 5002A.

7182

ALL MODELS HAVE THE VICKERS ADVANTAGES MENTIONED ABOVE



Single Stage. Pressures to 1,000 psi. Capacities to 55 gpm.

Two Stage. Pressures to 2,000 psi. Capacities to 55 gpm.

Double Pump—Two pumps for separate circuits driven by common shaft.

Two-Pressure Pump automatically delivers larger volume at low pressure and smaller volume at high pressure.

Compact new **Gast** rotary
No. 6 **Air Motor** delivers

TWO HORSEPOWER

. . . weighs only 17 pounds

Here's compact, light-weight power—offering many advantages as original equipment on your products! With the new 2 h.p. Model 6AM added to the line, Gast offers rotary air motors in five popular sizes from the 1/20 h.p. Model 1AM to the 4 h.p. Model 8AM.

To fulfill designers' needs, Gast also offers standard variations on some models, including foot or flange mountings for vertical or horizontal applications with direct or gear drive . . . special reversible rotation, etc. Well adapted for plant use or as original components, Gast Rotaries are *explosion-proof, variable in speed, burn-out proof* even when stalled—and low in first cost!

Wherever compressed air is available, they're a power source worth investigating! *Write for Model 6AM Bulletin 855*—or specify size that interests you. *Request "Application Ideas" Booklet too!* — **Gast Manufacturing Corp.**, P.O. Box 117 Benton Harbor, Michigan.

Original Equipment Manufacturers for Over 25 Years

GAST ROTARY

- **AIR MOTORS** TO 4 H.P.
- **COMPRESSORS** TO 30 P.S.I.
- **VACUUM PUMPS** TO 28 IN.

SEE OUR CATALOG IN SWEET'S PRODUCT DESIGN FILE

New Parts

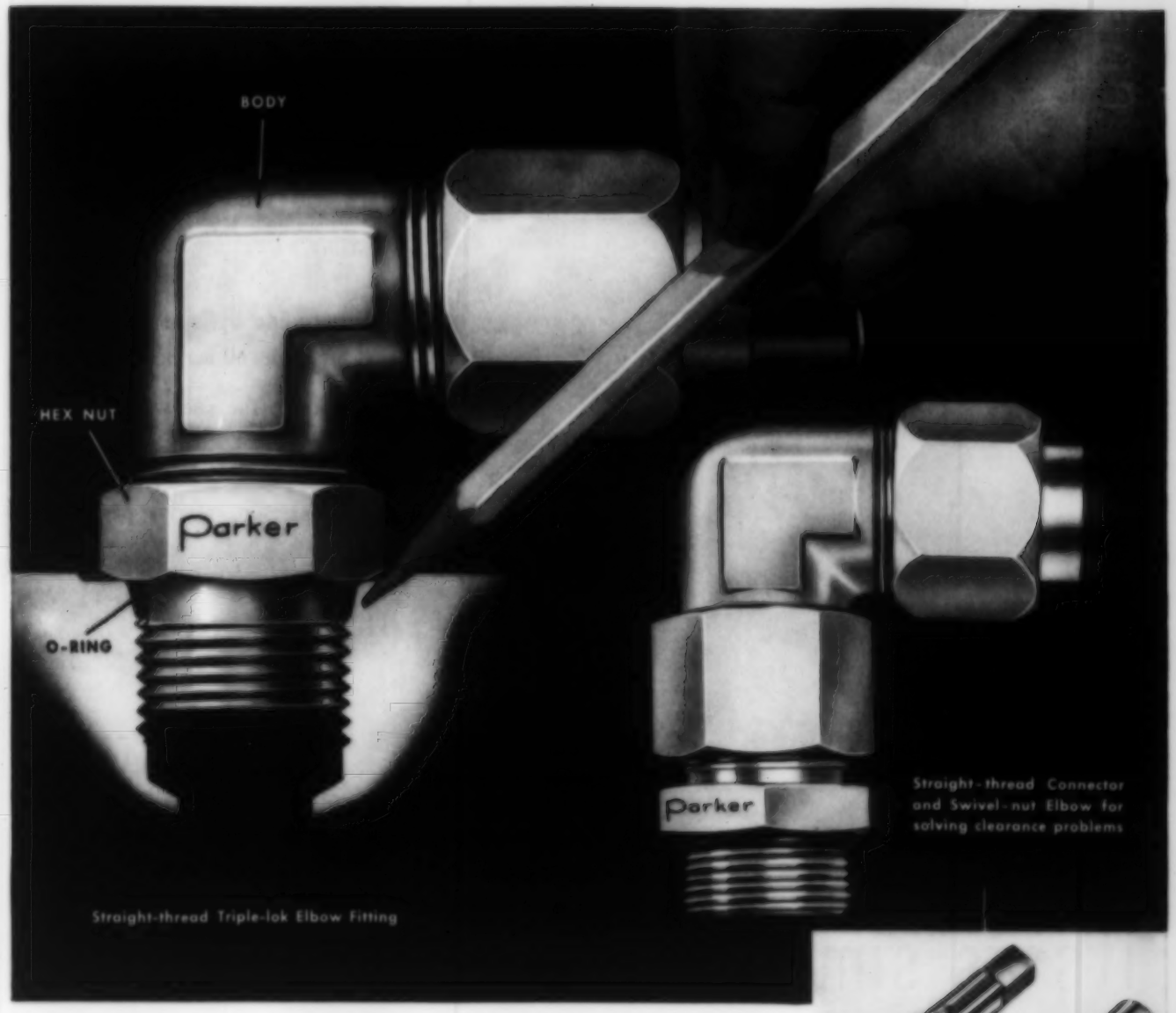
ment of fan-driven air. A large area of stator core is exposed to the circulated air. Air flow is supplied by a high-volume aluminum fan as well as rotor fans. Operating temperatures of totally enclosed, fan-cooled motors remain within the standard 55 C rise; in the open enclosures, temperatures remain within 40 C rise. Motors are made with cartridge type, double-shielded bearings. The system of greasing the bearings prevents their being overpacked with grease. Motor design also incorporates shock - resistant steel frame, cast iron end plates, Mylar film slot insulation, highly stable copper-clad rotor and steel feet which are welded to the frame. Made by **Howell Electric Motors Co.**, Howell, Mich.

Circle No. 79, Page 217, for more data

Fittings and Tubing 80

hand assembled without tools

Corrosion resistant uplasticized polyvinyl chloride fittings and flexible plastic tubing can be used in instrumentation. Assembly is entirely by hand, and the tubing can be cut with a knife or scissors. Fittings withstand maximum working pressures of 150 psi at 75 F and are furnished, as is tubing, in ¼ and ⅜-in. sizes. Available are half unions for joining plastic to male pipe thread, unions and bulkhead unions for joining plastic to plastic, connectors for



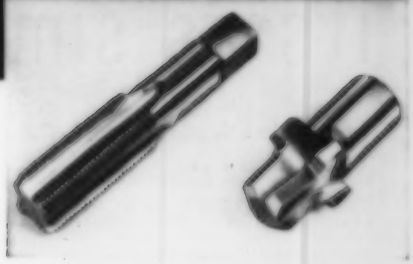
New Parker *straight*-thread fittings solve your leakage problems

Now you can forget about high-pressure hydraulic problems resulting from tapered pipe threads. Forget about leakage . . . about the danger of cracking or distorting valve bodies by over-tightening the fittings . . . about damaged threads from over-tightening to obtain proper positioning. Forget about messy pipe "dope".

You can eliminate all of these problems by using new Parker *straight*-thread fittings with positive O-ring seals. (See illustration above.)

Parker *straight*-thread fittings are now being supplied in response to the growing demand for this new type of leakproof, trouble-free connection. They are shorter and have smaller hexes than the AN fitting for the old AND 10050 boss. *Straight* threads are available on *Triple-lok* (the industrial standard flare tube fitting) and on *Ferulok* (flareless fitting for heavy steel tubing).

This is another example of Parker's pioneering leadership in the field of hydraulic fittings. Mail the coupon today for complete information.



Precision thread-tapping and counterboring tools for making accurate *straight*-thread boss (to receive these new Parker *straight*-thread fittings) are now available with machining drawings from Parker.

TUBE AND HOSE
FITTINGS DIVISION
Section 412-K

The Parker Appliance Company
17325 Euclid Avenue
Cleveland 12, Ohio

Send Catalog 4301.

Name_____

Company_____

Address_____

City_____ State_____

Parker

Hydraulic and fluid system components

Cutaway view of Robbins & Myers Shallow Well water pump with Apex covered universal joint connecting motor shaft and pump rotor.

it's as simple as that!

The single-thread, stainless steel rotor in an R&M pump turns within a double-thread, pliable rubber stator, forming tightly sealed cavities which carry the water with positive pressure and continuous flow. There are no pistons, gears, impellers or belts. But there IS an Apex universal joint connecting the motor shaft and the pump rotor. This universal joint with lubrication-retaining cover functions perfectly in a constant stream of water, compensating for the angular movement between the screw-type rotor and the rigid motor shaft.

How about YOUR universal joint application? Like to make it as simple as that? Apex universal joints function equally well in gases, liquids, corrosive atmospheres and in extremes of temperatures. Write today, on your company letterhead please, for your copy of Catalog 27 and the very helpful Universal Joint Application Data Sheets.

APEX universal joints

THE APEX MACHINE & TOOL CO.
1036 Patterson Blvd. • Dayton 2, Ohio

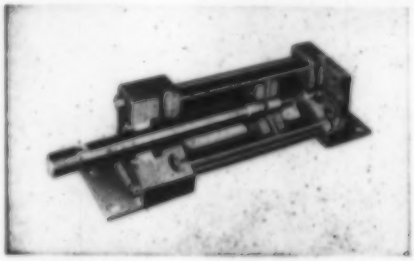
joining plastic to female type pipe thread and caps. Tubing is unaffected by most acids and alkalies and remains flexible at low temperatures. Made by **Tube Turns Plastics Inc.**, 224 E. Broadway, Louisville 1, Ky.

Circle No. 80, Page 217, for more data

Square-End Cylinders 81

for air or oil service

Adaptable for use with either air or oil, nonrotating, double-acting square-end cylinders are made in standard bore sizes from 1½ to 8 in. Maximum stroke of cylinder



actuated by air is 5 ft at 500 psi, 8 ft at 80 psi; maximum stroke with oil is 3 ft at 500 psi, 5 ft at 250 psi. Rod and blind end covers are of heavy steel plate and are square to minimize mounting area. The piston and rod are threaded and locked in place with a retaining nut to provide double security of all models with more than 3-in. bore. The cushion ball check and cushion adjusting valve are located on the same side of the cylinder for easy accessibility. Ports can be relocated to positions 90 deg apart by rotating the cylinder covers. Proper compression is maintained by tightening tierods by means of torque type nuts. Made by **Logansport Machine Co.**, Logansport, Ind.

Circle No. 81, Page 217, for more data

Temperature Controller 82

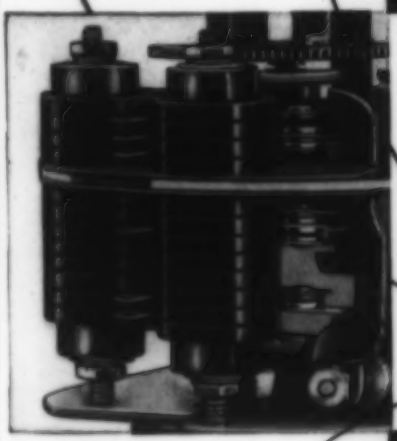
in ranges up to 0-2500 F

Temperatures as high as 2500 F can be held and controlled to within ±1 per cent of scale by model PB AIC indicator/controller. Operating on less than 1 ma current, it provides both straight cut-off and simple on-off control as required for industrial

NEW Cramer

from face to terminal block

type 412
TIME DELAY RELAY



NEW—Repeat Accuracy within ± ¼ of 1% of full scale (30 sec. and longer ranges); ± ½ of 1% on faster timers.

NEW—Full Vision Dial. 300 degree scale assures precise settings and fast, accurate readings. Dial and pointers protected by transparent cover.

NEW Contacts, rated 15 amps., give positive quick-make, quick-break operation. Contacts are of silver cadmium oxide with ability to handle high inrush currents.

NEW Flexibility in wiring. Nine-position terminal block offers side or rear connection, presents a variety of wiring possibilities.

NEW Reset Shock Spring Design laboratory tested for more than a million operations.

NEW Friction Setting Mechanism allows adjustment even while timer is operating.

NEW—Ratchet Clutch operated by powerful relay, provides instant action, no slip.

NEW O-Ring Retainer permits quick removal of bakelite housing, exposing entire timer mechanism.

Timer driven by high torque (30 in. oz. at 1 r.p.m.) Cramer Type 112 Synchronous Motor.

Cramer TIMING DEVICES

The **R. W. CRAMER CO., Inc.**

SPECIALISTS IN TIME CONTROL
BOX 6, CENTERBROOK, CONNECTICUT

18CR88

Sikorsky rotor heads stress ESNA

A 16-year fastener field test

How many different stresses are exerted on this rotor head as it controls the cyclic and collective pitch of the five main blades of the Sikorsky S56 designed to transport 26 fully equipped troops? Since it also transforms engine power into forward motion or vertical flight, the stresses add up to an interesting but complicated problem in dynamics. Notice that Sikorsky has solved the fastening problems related to this rotor head design with dozens of standard hexagon and double hexagon Elastic Stop nuts.

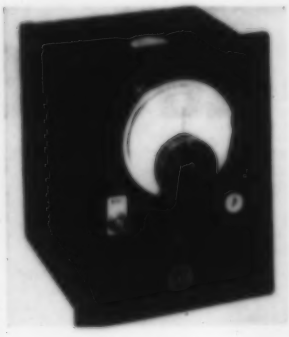
They are self-locking, maintain precision adjustments and assure fastener security under the vibration and stress loads normal to helicopter flight.

Sikorsky Aircraft Company had been using Elastic Stop nuts for over a decade before it began developing rotary wing aircraft in 1939. They have been a steady ESNA customer for 27 years and Elastic Stop nuts have been a standard fastener on every new Sikorsky design.

If you recognize the practical value of almost three decades of "flight tested" experience on all types of air frames and engines . . . you'll rely on Elastic Stop® nuts.

ELASTIC STOP NUT CORPORATION OF AMERICA

Department N83-114 • 2330 Vauxhall Road • Union, New Jersey



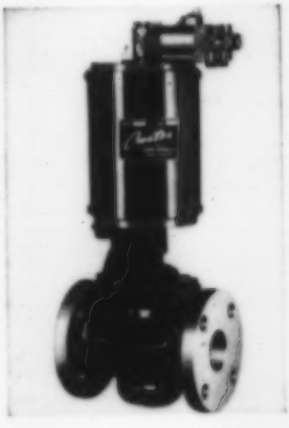
furnaces, ovens, tanks or similar production equipment. The control consists of an indicating pyrometer unit and an electronic control unit which opens and closes load relay to regulate fuel supply. Both are housed in a compact case. Capacity is 5 amp at 115 v. Circuit contacts are graphite coated and draw less than 1 ma at 25 mu w. Instrument can be surface or flush mounted. Available ranges are 0 to 600, 1000, 1500, 2000 and 2500 F. Made by **Automation Instrument Corp.**, 1516 Summer St., Philadelphia 2, Pa.

Circle No. 82, Page 217, for more data

Rotary Actuator 83

for remote control of valves

This hydraulic or pneumatic control device has an internal helix arrangement which converts the in-line motion of a hydraulic or pneumatic cylinder into a rotary

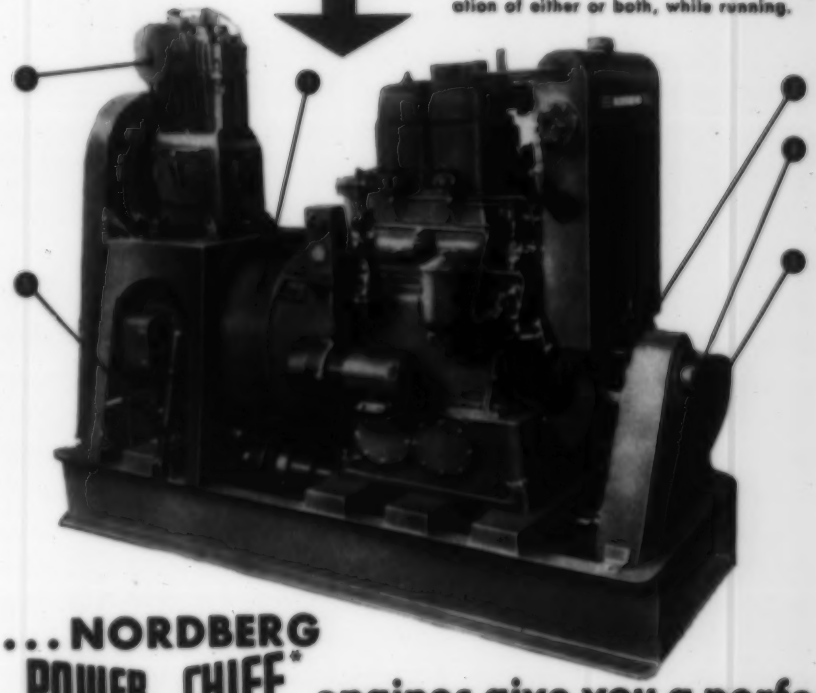


movement. It is especially applicable to the remote control of valves and can be operated with air, gas or hydraulic pressure. The actuator can be built to produce almost any degree of rotary movement up to 360 deg or more.

(*Continued on Page* 240)

Look at all the jobs this "POWER PACKAGE" will handle

- **ELECTRIC GENERATOR** . . . available in both AC and DC types, in capacities from 6 to 30 kilowatts.
- **INTEGRAL AIR COMPRESSOR** . . . ball bearing type, two-stage air compressor, in capacities from 5.4 to 27.3 cu. ft. per minute.
- **CENTRIFUGAL WATER PUMP** . . . (not shown) wide range of sizes available, from 60 to 250 gallons per minute, at heads from 30 to 80 feet.
- **FRONT END STUBSHAFT** . . . supported by outboard bearing, for handling wide range of power take-off needs.
- **TWIN DISC CLUTCHES** . . . transmit power to pump and air compressor—allows operation of either or both, while running.



. . . NORDBERG POWER CHIEF* engines give you a perfect match of MACHINERY and POWER!

This two-cylinder Diesel generating unit was designed and built to meet a specific need for combining several power jobs in one compact unit. Utilizing a "standard" Nordberg POWER CHIEF Diesel engine, this power unit points up the fact that you can get "stock" engine economy in an "engineered power package" by letting Nordberg engineering facilities help in providing a *perfect match of power and machinery*.

In the range of 10 to 45 horsepower, or 6 to 30 kilowatts, Nordberg POWER CHIEF Diesels can be furnished with the type of drive, generator or special equipment you need to meet your specific power needs.

*Trademark

NORDBERG MFG. CO., Milwaukee, Wisconsin

NORDBERG

Builders of America's Largest Line of Heavy Duty Diesels

MAIL COUPON FOR DATA

Nordberg Mfg. Co., Milwaukee, Wis. MD

Please send full details on Nordberg POWER CHIEF

☐ Diesel Engines ☐ Spark-Fired Gas Engines

(Check one or both)

Name_____

Company_____

Address_____

City_____ Zone____ State_____

© 1955, Nordberg Mfg. Co. 4-355-OEM

Jack & Heintz Motors answer

HERE WAS THE NEED

Overhead Door Corporation, Hartford City, Ind., one of the world's largest manufacturers of upward-acting garage doors, offer a complete line of electric door operators for residential, commercial and industrial use. To fulfill rigid requirements for added features, their engineers demanded specially designed motors.

These motors had to assure fast, dependable starts—quick, positive stops—instant reversing without hesitation or drift. Their design had to guarantee efficient performance under every condition. For these reasons, Overhead Door turned to Jack & Heintz.

Customized ELECTRIC

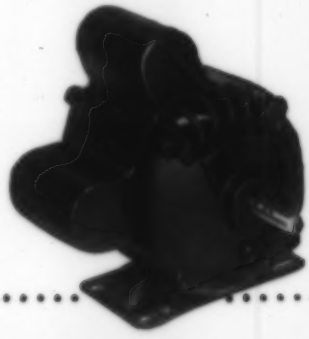
toughest job requirements for

THE "OVERHEAD DOOR" TRADE MARK

Provide the many *extras* required for top-flight door operation!

Because electric motors must do far more than *power* the push-button or electronically controlled operators made by Overhead Door Corporation, Jack & Heintz motors are designed specifically for each requirement of the application.

These motors must operate smoothly, quietly, surely—one or one thousand times a day—regardless of climate or temperature extremes. In addition, they are *customized* to work in restricted mounting locations . . . and provide *extra* features that guarantee years of trouble-free door operation.



Instant Reversing!
No hesitation or drift! Simplified control circuits are achieved by the specially designed Jack & Heintz 3-wire motors.

Positive, Dynamic Braking!
For cushioned, controlled stops preventing shock damage to door or track. Special electric circuit assures this desired performance.

High Starting Torque!
Equally effective in either direction. Special winding design provides maximum power at the start, minimum current demand.

Customized Configuration!
Capacitor, relay, terminal box, end bell and name plate are all ingeniously positioned to customer's exacting service and installation requirements.

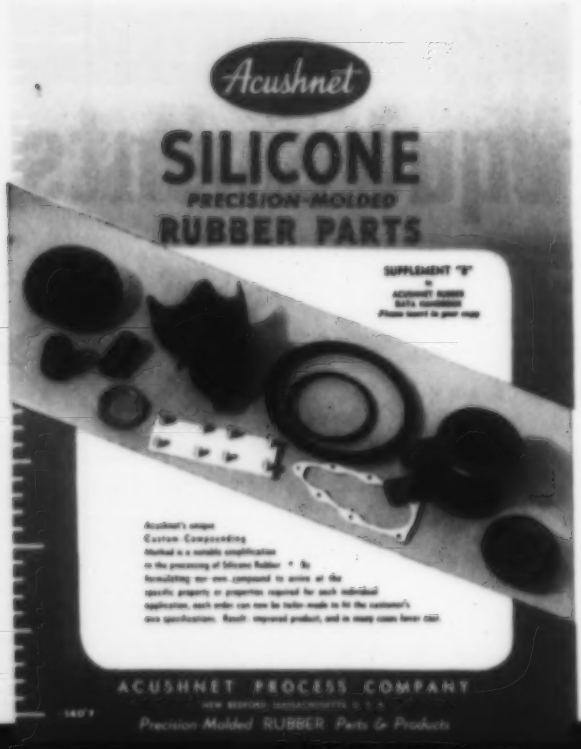
DESIGN YOUR PRODUCT TO DO A JOB . . .

not to fit a motor

Avoid compromising your product design by taking advantage of an engineering philosophy that will answer your special motor needs. Design your product to do a job . . . not to fit a motor! Write Jack & Heintz, Inc., 17626 Broadway, Cleveland 1, Ohio.

© 1955, Jack & Heintz, Inc.

MOTORS *by* JACK & HEINTZ



SILICONE RUBBER *Custom-Compounded*
TO MEET *Your Own* **SPECIFICATIONS**

Acushnet's Custom-Compounding Method is a notable simplification in the processing of Silicone Rubber, the remarkable material that resists temperature extremes from +600°F to −140°F.

By using the versatile Silicone *gums*, we formulate our own compound to obtain the specific property or properties required for each individual application. This eliminates large inventories and involved "doctoring" of standard pre-mixed stocks.

Many times, a lower cost formulation can be used which will perform in the particular application as well or better than any available pre-mixed stocks.

Each order can now be tailor-made to fit the customers' own specifications or requirements. As a result, production time is shortened, better product performance is obtained, and in many applications the cost is reduced.

When customers still specify a standard stock suitable for application we gladly produce the required part.

Acushnet

Send for a copy of the Silicone Rubber parts brochure illustrated above — an interesting, informative compilation of Silicone Rubber Data, with illustrations and descriptions of typical and unusual applications.

Acushnet Rubber Data Handbook also available on request.

ACUSHNET PROCESS COMPANY

Address all communications to 762 Belleville Ave., New Bedford, Mass.

New Parts

(*Continued from page* 237)

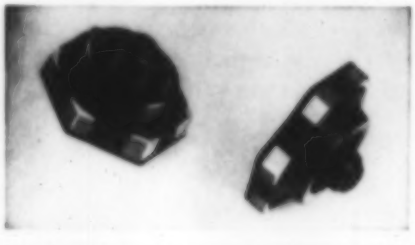
Switches can be employed to stop the actuator at any rotation point, and a slip clutch can be used to vary rotary sequences. Five standard models made with 3, 4, 5, 6 and 8-in. bore provide torque ranging from 350 to 3360 lb-in. at 100 psi. The actuator is completely enclosed. Its hollow piston rod permits lubrication of plug valves through the center. Mounting brackets for all types of valves are available. Made by **Carter Controls Inc.**, 2800 Bernice Rd., Lansing, Ill.

Circle No. 83, Page 217, for more data

Rubber Panel Seal 84

for toggle switches

Silicone rubber model 3268 panel seal protects toggle switches from water, dust, moisture, explosive or combustible liquids, vapors and gases. It also is resistant to ozone attack and fungus growth. The seal acts as a locknut in securing



the toggle switch to the panel, minimizing loosening under shock and vibration. It is comprised of a molded rubber member cemented to a threaded stainless steel insert. The rubber member is formed in such a way that it grips the toggle lever firmly but does not hinder its movement. Seals are available in tan, red, gray, white and black and can be used in the temperature range of −60 to 200 C. Made by **Panseal Inc.**, 10 Main St., Little Ferry, N. J.

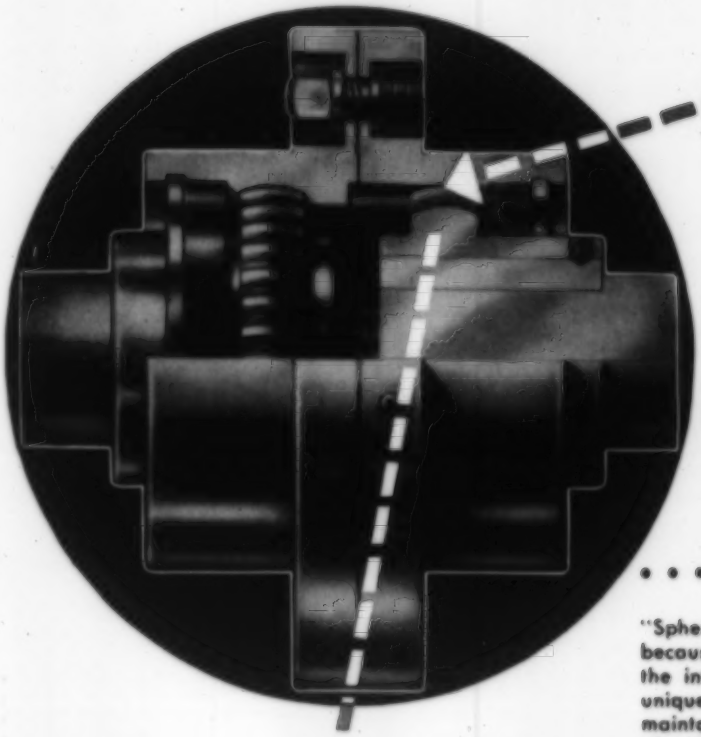
Circle No. 84, Page 217, for more data

Magnetic Brake 85

for use in 25 to 50 hp range

Improved mechanical design of style H series 1000 magnetic brake enables it to develop higher torque, yet take up less space than style it replaces. Unit is designed for use in 25 to 50 hp range

INVESTIGATE the advantages



SPHEREFLEX®

FLEXIBLE COUPLINGS

...and you'll buy them

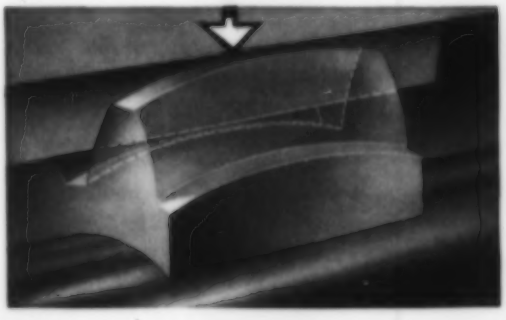
"Sphereflex" is entirely *different* than any other coupling, because the male teeth are cut on a "true spherical arc" and the internal teeth are cut with a "straight root" . . . This unique combination permits the curved teeth to constantly maintain a *full line of contact* with the internal teeth, *even when the coupling is flexed;* in addition, this feature makes it *absolutely unnecessary* to depend upon excessive backlash between coupling teeth, point contact or springs, in order to secure true flexibility. Size for size, "Sphereflex" Couplings will withstand higher horsepowers and greater mis-alignments than any other comparable couplings.

Standard "Sphereflex" Couplings will compensate for angular mis-alignment up to 3½° plus or minus on each coupling half, or a total of 7°, (special couplings are available for mis-alignments up to 14°). Due to this angular capacity, the "Sphereflex" Coupling can offer much greater parallel misalignment with minimum backlash. "Sphereflex" Couplings are priced competitively with ordinary commercial gear couplings.

When you buy "Sphereflex" Couplings, you secure the background of 64 years in power transmission engineering and experience, covering thousands of jobs in every line of industry and transportation.

If you have a Coupling problem, "Phillie Gear" Sales Engineers can help you to secure a cost-saving and effective solution . . . Phone, wire or write for our new coupling Catalog #C-540.

NOTE—
teeth are cut on a true spherical arc



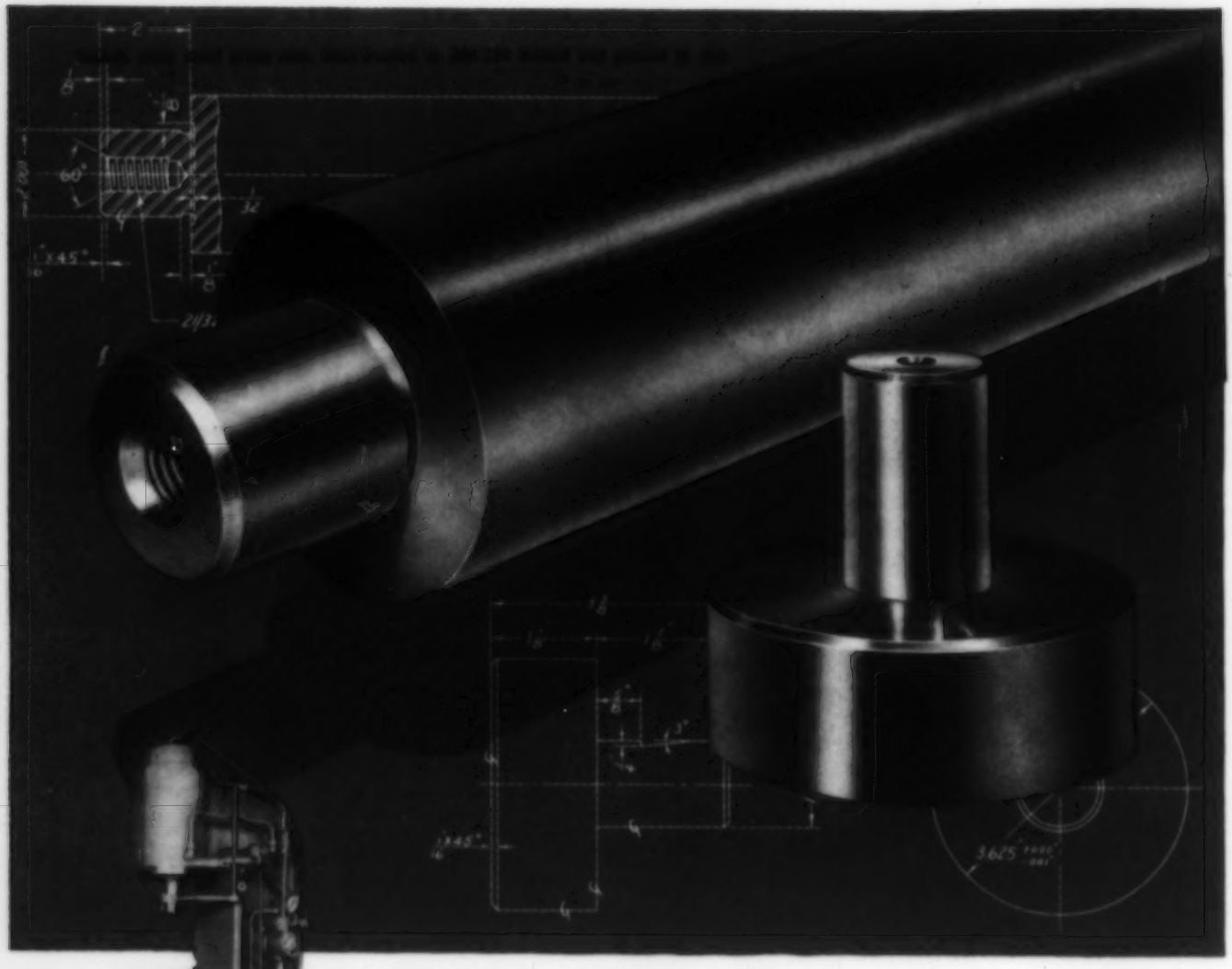
PHILADELPHIA GEAR WORKS
INCORPORATED

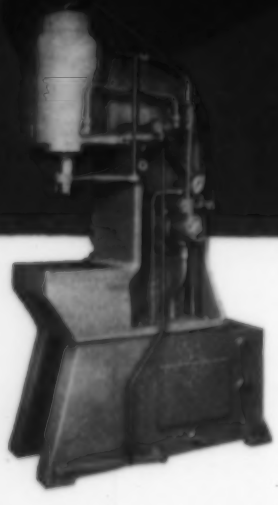
ERIE AVE. AND G ST., PHILADELPHIA 34, PA.

NEW YORK • PITTSBURGH • CHICAGO • HOUSTON • LYNCHBURG, VA.
BALTIMORE • CLEVELAND
Virginia Gear & Machine Corp., Lynchburg, Va.

Industrial Gears & Speed Reducers • LimiTorque Valve Controls

Established 1892





MAX-EL Alloy Steel means no distortion—longer wear in 15-ton hydraulic press ram

To keep this 15-ton press operating day after day for years of dependable service, takes *special* steels. For example, even after thousands of cycles of operation, the ram *must* remain accurately in line with the work table. *It demands a steel that will not distort, set or wear.*

That's why both the ram and ram-plug are made of Crucible MAX-EL alloy steel. In fact, the manufacturer, Greenerd Arbor Press Co., Nashua, N. H., has been a steady user of MAX-EL for many years.

Here's what they have to say—*"We have tried many grades of steel, but we find that MAX-EL 3½ heat-treated in the bar works out better for our application."*

And it probably will for yours, too. So when you have a job calling for a non-deforming alloy steel—one with excellent machinability, high-strength and wear-resistance—try Crucible MAX-EL. It's promptly available from your nearby Crucible warehouse, in the sizes and grades you need. *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

Write for your free copy of this Crucible Publication Catalog listing dozens of helpful booklets and data sheets.

CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

with both old and newly rerated NEMA frame sizes. It requires 6 in. less clearance for housing removal than previous model. Length has been reduced 2¼ in. and weight reduced. Two available sizes are rated 125 and 175 lb-ft torque. Brake can also be supplied for floor mounting. Made by **Stearns Magnetic Inc.**, 635 S. 28th St., Milwaukee 46, Wis.

Circle No. 85, Page 217, for more data

Steel Primer 86

dries in 10 minutes at 85 F

Rustbond primer No. 6 can be used over wire-brushed, rusty and sand-blasted steel, as well as on clean cold-rolled (bright) steel. It dries in 10 minutes at 85 F to form a coating which resists peeling and flaking. Dry film thickness is 2 mils. Primer is compatible with topcoats of vinyls, phenolics, alkyds, chlorinated rubbers, neoprenes, oil-base paints and furans. Made by **Carboline Co.**, 331 Thornton Ave., St. Louis 19, Mo.

Circle No. 86, Page 217, for more data

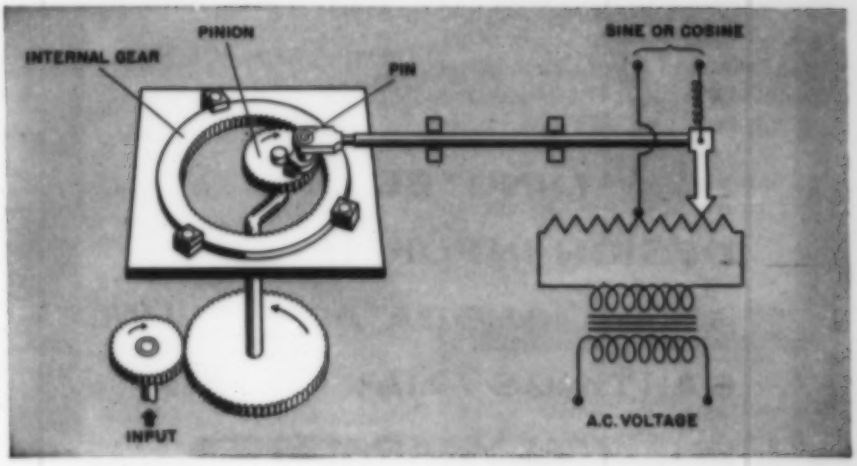
Limit Switches 87

water-tight for use on machine tools

Improved line of heavy-duty Lox-switch machine tool limit switches is designed to withstand water, dust and oil under severe operating conditions. These NEMA types 1-A, 2, 4 and 5 combine O-ring shaft seals, captive cover screws, water-tight switch covers and six back cover screws to form the positive water-seal. Available styles include double-pole, single-throw, double-break; three-pole, double-break; and neutral position, double-throw, double-break styles,

(*Continued on Page* 246)

SINCE 1915 LEADERS IN AUTOMATIC CONTROL



Ingenious electro-mechanical device generates sine or cosine function

From a combination of mechanical and electrical principles, Ford Instrument Company engineers have produced and patented an electro-mechanical device to generate sine and cosine functions. The mechanical portion is an internal-gear angle resolver. It consists of two gears – an internal gear and a pinion. Because the pinion has exactly half the number of teeth as the internal gear, the pin on its pitch circle traces a straight line when the pinion rolls inside the angle gear.

Furthermore, the displacement of the pin relative to the center of the internal gear is proportional to the sine (or cosine) of the roll angle of the pinion.

If a linear potentiometer is now placed along the diameter of the internal gear and a potentiometer slider is fastened to the pin on the pinion, the voltage picked off by the brush is proportional to the sine (or cosine) of the angle.

Two such systems, connected in tandem, produce simultaneously both the sine and cosine functions.

This is another example of Ford Instrument engineering ingenuity. What appears on the surface to be a complex problem is solved by the combination of well-known principles.

Perhaps you have a problem that could benefit from Ford Instrument experience. Ford Instrument engineers work every day with systems using mechanics, electronics, hydraulics, electro-mechanics, magnetics, atomics. How can Ford help you?

79

FORD INSTRUMENT COMPANY
DIVISION OF SPERRY RAND CORPORATION
31-10 Thomson Avenue, Long Island City 1, N. Y.

ENGINEERS
of unusual abilities can find a future at FORD INSTRUMENT COMPANY. Write for information.

(Advertisement)

7 MINUTES OF DESIGN INFORMATION ABOUT ALCOA ALUMINUM CASTINGS THAT COULD PUT YOU YEARS AHEAD OF COMPETITION.

YOUR PRESENT PART IN CAST IRON VERSUS LARGE PERMANENT-MOLD CASTINGS

On the pure chance of saving a buck, we heartily suggest that any designer now thinking of cast iron turn a calculating eye in the direction of aluminum permanent-mold castings. Our reasoning goes like this:

1. Cast iron *must* be cast in fairly thick sections—often stronger than you need. This isn't true of aluminum, and the resulting weight saving often is larger than the accepted ratio of 2.6 to 1.

2. Big iron castings usually require large dry sand cores. This isn't cheap in a foundry. If quantities are reasonable, the cost of an aluminum permanent-mold casting becomes extremely competitive.

3. The lighter weight of an aluminum casting over its iron counterpart lowers shipping costs, eases handling during machining and speeds installation.

4. Aluminum's natural advantages over iron—notably resistance to corrosion—can materially reduce maintenance costs.

5. Faster feeds and speeds possible in machining aluminum as compared to cast iron.

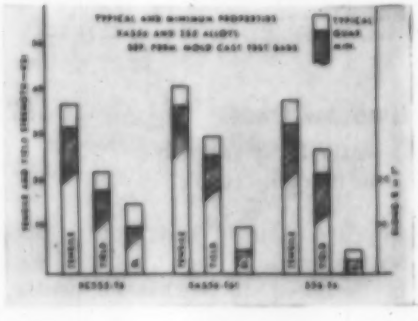
Proof of the foregoing pudding is in two recent jobs previously made in cast iron—now doing better in aluminum P. M. One is a large gas meter case. In iron, it weighed 500 pounds assembled. In aluminum, 175 pounds. Pressure tests prove it's stronger, and corrosion tests indicate practically no maintenance. Further savings are realized by easier handling and installation. The other job is bases for street lighting poles. Here the saving in maintenance is considerable, too. In both instances, use of Alcoa's research and development facilities clinched the economic argument in favor of aluminum. We can do that kind of thing for you, too.

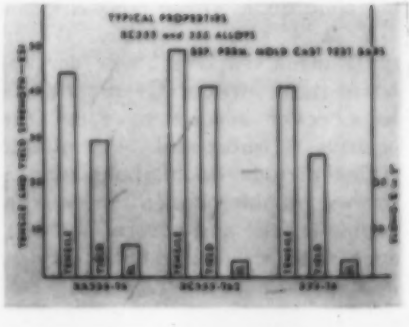
In iron it weighed 500 pounds . . .

WHAT'S NEW WITH ALLOYS?

Every time you turn around these days, it seems somebody has brought out a new casting alloy. We're no exception. And while we applaud the spirit of progress, we urge buyers of aluminum castings to look behind the scenes a little. Is the introduction of a nonheat-treatable alloy an advantage to the buyer, or to the foundry that has no heat-treating facilities? While a nonheat-treatable alloy may have fine properties in test bar, how it performs in the casting depends on more than alloying constituents. Metal handling, casting technique and metallurgical control are equally important. All of which says it pays to know your foundry as well as your alloy.

Having thus cautioned you, we now blow our own horn about two new Alcoa-developed alloys for permanent-mold casting: XC355 and XA356. These are new high-strength, high-elongation alloys that require careful control of impurities and careful foundry handling. Both are heat-treatable. Both can be handled in Alcoa foundries that are fully equipped to deliver close to test bar properties in your finished casting. The little bar charts below compare tensile, yield and elongation with the familiar 355 and 356. Structural assemblies and parts subject to impact seem most likely candidates for these new alloys. Any ideas?





"PRECISION CASTINGS"? ± 1/32" or ± 0.005"

Close tolerance casting has its justification in terms of the subsequent machining it can eliminate. These days, close tolerance is a loosely used term meaning somewhat less than plus or minus 1/32". You'll find no shortage of foundries who are willing to take on a close tolerance job. There are proponents of everything from shell molding to investment casting. Each is willing to argue the advantages of whatever process they have equipment to produce. Since it is impossible for any foundry to work by all methods, it becomes the supplier's difficult choice to pick one or two. This Alcoa did several years ago.

Cast with thin steel inserts . . .

Not a speck of finish machining . . .

Precision casting at Alcoa is done in plaster and tolerances of 0.005" are not unusual. Parts we are currently making in plaster include automobile tire molds with thin steel inserts, called "sipes," to give tires a squeegee action on slippery pavement. Also for the automotive trade, we are making molds for rubber and plastic arm rests and dashboard covers. These have the characteristic leather grain cast into the mold. Thin-bladed torque converter parts are also being cast in plaster. In every case, not a speck of finish machining is necessary on the as-cast surface. The experience we have gained in such production is readily available to you.

A very profitable sandwich . . .

JOINING ALUMINUM CASTINGS —SANDWICH BRAZING

We're seeing more and more complex castings being broken down into a series of simple castings and then joined back together.

The machine tool valve body, shown above, is a case in point. As you can see, it has a series of intricate passageways to control hydraulic fluid. This part replaces many lines and fittings. It is practical only because it can be made inexpensively.

In this case, the center section is a sand casting of C612 alloy. The cover pieces are then brazed to the center casting by a furnace operation. Other applications of this technique are oil-cooled pistons for diesel engines, fuel regulator housings for jet engines, wave guides for radar equipment and cylinder heads for engines. We have had considerable experience with this sandwich-type construction, and are in a position to offer some interesting suggestions on any cast part that would apply.

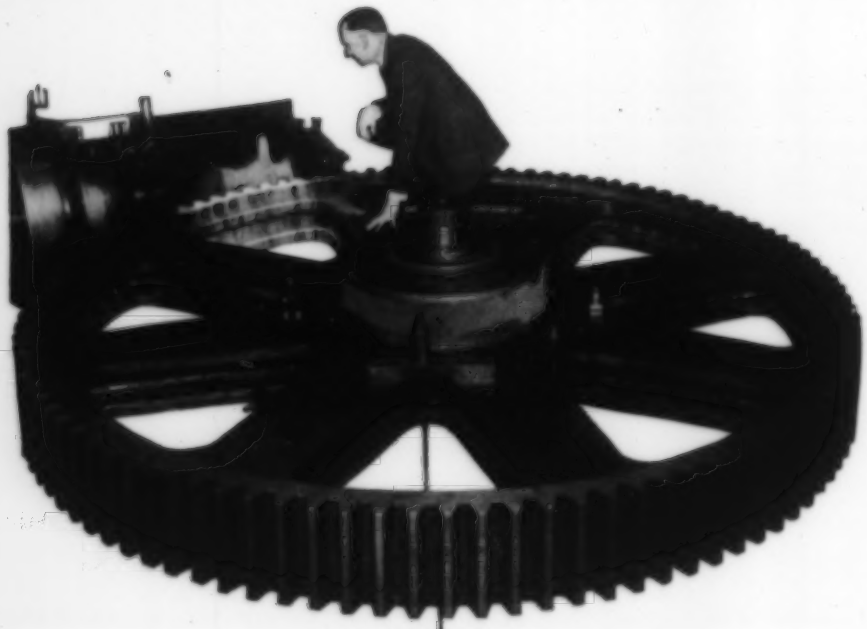
STRAIGHT TALK

It is a fact that a hard look at aluminum castings has put a competitive edge on many a designer's thinking. When you take that look, you needn't be confined by one or two casting processes because Alcoa foundries produce all kinds—sand, die, permanent-mold, plaster and combination mold. To contribute solid technical thinking, at the design stage, your local Alcoa sales engineer is listed under "Aluminum" in your phone book. Use him. Or write to Aluminum Company of America, 1991-K Alcoa Building, Pittsburgh 19, Pa.

Your Guide to Aluminum Value

ALCOA ALUMINUM

ALWAYS FASTEN ALUMINUM WITH ALCOA® ALUMINUM FASTENERS



10 TONS
OR ONE OUNCE

Horsburgh & Scott Gears Meet Your Requirements Exactly

You can get practically every kind and every size gear you need from Horsburgh & Scott. Expert engineering, skilled craftsmanship and top quality materials assure you of the best possible gears for every job.

Our years of experience engineering and manufacturing all kinds of gears and speed reducers is available to help you in the design and selection of the best gearing for your application.

If you have a gear or speed reducer problem our engineers will be glad to help you. Just send us the details or call. There is no obligation.

Send note on Company Letterhead for complete H & S Catalog.

THE HORSBURGH & SCOTT CO.
GEARS AND SPEED REDUCERS
5112 Hamilton Avenue
Cleveland 14, Ohio

New Parts

(Continued from Page 243)

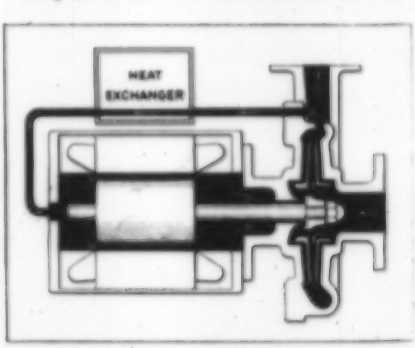
both normally open and normally closed. Over 150 lever styles are offered. All models have isolated circuits and incorporate a glass fiber arc shield. Made by **R. B. Denison Mfg. Co.**, 102 St. Clair Ave., N. W., Cleveland 13, O.

Circle No. 87, Page 217, for more data

High-Temperature Pump 88

handles fluids at 1000 F

Integral heat exchanger is combined with high temperature pump design in leakproof "canned motor" Chempumps, developed for handling Dowtherm, Arochlor, hot fats and oils and similar fluids at high temperatures. Pumped fluid entering the rotor chamber encounters a "necked down" area between motor and pump which provides a thermal barrier and narrow restriction for passage of hot pumped fluid. A secondary impeller mounted on the rotor circulates rotor chamber fluid through a water cooled heat exchanger. Depending upon cooling water temperature, pumps can handle fluids up to 1000 F. Model CHS pumps are offered in 5 and 7½-hp sizes and model CFT units in ¾ and 1½-hp sizes. Maximum head developed is 195 ft and maximum ca-



SAVED $103.46 PER RING!

Switching to Flash Butt-Welding of Mill-Rolled Sections, Slashed Production Cost 76½%

NEW METHOD

Ring, rolled and welded from mill section of approximate shape of finished part.

OLD METHOD

Ring, rolled and welded from rectangular bar size to maximum overall dimensions of finished part.

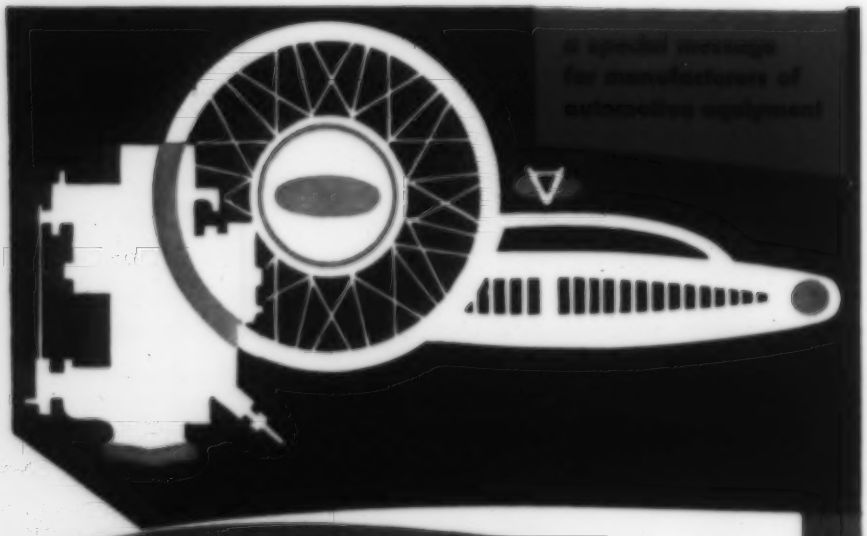
Rough rings purchased by a well known manufacturer of jet aircraft engines weighed 135 pounds each. Most of this weight was excess metal which had to be machined away. American Welding's Industrial Products Division, working with this company, studied blueprints and recommended a flash butt-welded ring, formed from a special mill-rolled section. Adopting this new ring saved 88 pounds of metal and eliminated much of the machining time required. American Welding now produces thousands of these rings, in a rough-machined state, at less than one-quarter of the original cost.

Would you like to know more about American Welding and what savings it may help to effect on products which you manufacture? Write today — we will be glad to study your problem.

Free Catalog of American Welding Facilities. Send for Your Copy TODAY.

AMERICAN WELDING

THE AMERICAN WELDING & MANUFACTURING CO.
130 DIETZ ROAD • WARREN, OHIO



a special message for manufacturers of automotive equipment

need a finish for low cost corrosion protection or showroom sparkle?

specify IRIDITE

Whether you're finishing non-ferrous parts for high corrosion protection, paint base, or for showroom sales appeal, you can be sure of low material and production costs and peak performance when you specify Iridite. Here's what you can do with Iridite:

- **ON ZINC AND CADMIUM** you can get highly corrosion resistant finishes to meet any military or civilian specifications and ranging in appearance from olive drab through sparkling bright and dyed colors.
- **ON COPPER . . .** Iridite brightens copper, keeps it tarnish-free; also lets you drastically cut the cost of copper-chrome plating by reducing the need for buffing.
- **ON ALUMINUM** Iridite gives you a choice of natural aluminum, a golden yellow or dye colored finishes. No special racks. No high temperatures. No long immersion. Process in bulk.
- **ON MAGNESIUM** Iridite provides a highly protective film in deepening shades of brown. No boiling, elaborate cleaning or long immersions.

AND IRIDITE IS EASY TO APPLY. Goes on at room temperature by dip, brush or spray. No electrolysis. No special equipment. No exhausts. No specially trained operators. Single dip for basic coatings. Double dip for dye colors. The protective Iridite coating is not a superimposed film, cannot flake, chip or peel.

WANT TO KNOW MORE? We'll gladly treat samples or send you complete data. Write direct or call in your Iridite Field Engineer. He's listed under "Plating Supplies" in your classified telephone book.

Iridite is approved under government specifications

ALLIED RESEARCH PRODUCTS INCORPORATED

4004-06 E. MONUMENT STREET • BALTIMORE 5, MD.

New Parts

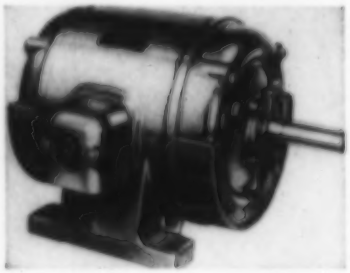
pacity is 250 gpm. Made by **Chempump Corp.**, Station I, 1300 E. Mermaid Lane, Philadelphia 18, Pa.

Circle No. 88, Page 217, for more data

Cool-Running Motors 89

incorporate turbine type fans

A high-capacity turbine type fan mounted on the motor shaft of ACEC open dripproof motor serves with the usual integral cooling fans at each end of the rotor to further reduce motor operating temperatures. Also contributing to



lower operating temperatures is precision-aligned stacking of stator laminations, which minimizes temperature rise due to eddy currents. Formacec insulation facilitates heat dissipation. Made by **ACEC Electric Corp.**, 40 E. 49th St., New York 17, N. Y.

Circle No. 89, Page 217, for more data

Coated Steel Tape 90

covered with any of three plastics

Strength of steel is combined with dielectric properties, abrasion resistance and other service factors of plastic in Met-L-Tape, a plastic covered metal tape. Vinyl, nylon or polyethylene plastic is extruded over high tensile steel strap to protect it from corrosion. Tape can be fastened by bolts or rivets or, by stripping a section of the plastic to expose the metal, it can be spot welded. Coatings are

RB&W FASTENER BRIEFS

RUSSELL, BURDSALL & WARD BOLT AND NUT COMPANY

Technical-ities

By John S. Davey

Selecting the right grade of bolt

With few exceptions, the true function of a bolt is to clamp members together, and not to act as an axle or fulcrum. The residual tension set up in the bolt keeps joints tight.

There's rarely need for costly alloy steel fasteners — not when 3 physical grades of steel can satisfy most "clamping" applications.

SAE grade 1 offers 55,000 psi minimum tensile strength; grade 2, 68,000 psi; and grade 5, approx. 120,000 psi.

The first is used for fasteners which are stress-relief annealed to increase ductility. The next provides low carbon fasteners with a bright finish. The last goes into high-carbon, heat treated black fasteners identifiable by three radial dashes on the head.

SOME SUGGESTIONS

In terms of holding power, the stronger bolts and cap screws can cost you less than the cheaper bright ones. For example, either a ⅝" with three radial dashes or a ¾" bright cap screw can be used for a safe working load of 20,000 pounds. But being smaller, the high strength one costs less. However, if the same diameter is desirable, then fewer bolt holes need be made and faster assembly achieved when a product is designed to make use of high strength bolts.

In short, for more pounds of clamping effort per dollar, use high strength fasteners; for more pieces per dollar, use the lesser grades.

Cold Punched Nuts add to safety factor

NUTS dilate when tightened on a bolt. They also adjust plastically to distribute the load over many threads. Since nuts are overdesigned to be stronger than the bolt, these stresses can be disregarded for all practical purposes.

How a defect in hex bar caused split in nut machined from it.

Drift punch had to distort cold punched nut severely, far beyond its yield point before it cracked.

There are times, however, when nuts with optimum assurance against service failure are desired. In such cases, it pays to consider use of RB&W cold punched nuts.

These nuts are punched at right angles to the metal's flow lines . . . same direction as stress encountered in service. No unrelieved stresses are set up. The initial punching automatically reveals any defects. Repunching, an RB&W development, then not only trues up the hole for clean, concentric threads, but also serves as a drift punch test, automatically checking the soundness of these safest of nuts.

For help in applying standard fasteners to assure more assembly strength and less assembly time, feel free to call in an RB&W man. Russell, Burdsall & Ward Bolt and Nut Company, Port Chester, N.Y.

Plants at: Port Chester, N.Y.; Coraopolis, Pa.; Rock Falls, Ill.; Los Angeles, Calif. Additional offices at: Ardmore, (Phila.), Pa.; Pittsburgh; Detroit; Chicago; Dallas; San Francisco.

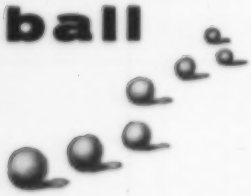
One-piece fastener better than two

One particular oil filter used to be fastened with stud and cap sleeve made by screw machine. This was only until RB&W pointed out that a one-piece fastener could be formed easily on a cold header. The advantages gained are obvious. The single fastener *cost* less, and took *less time* to assemble.

RB&W makes a tremendous variety of strong, uniform standard fasteners to improve assembled metal products. If any of these don't fill a particular need, perhaps an RB&W "special" can be developed that will.

Stuck for Ideas?

consider a ball



You're working on a new product. Or you're trying to improve an old one. You've tried one design after another, but none of them jell. Something's missing . . .

Is it a ball? A *Universal* ball?

Every day, designers and manufacturers are discovering *new uses* for balls *precisioneered* by Universal. Many of these new jobs are possible today only because of the infinite perfection that Universal puts into *every* ball it makes—whether it's pin-head small or golf-ball big. In chrome and stainless steel, this perfection means accuracy that is *better* than ten-millionths of an inch!

Yes, Universal Balls have what designers and manufacturers are looking for. They're *full* of ideas. May we tell you a few?

Universal Ball co.

WILLOW GROVE
MONTGOMERY CO., PA.

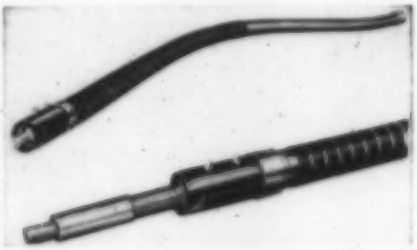
available in any color and can be heat sealed at the ends. Made by **Garrison Co.**, 218 Front St., South Plainfield, N. J.

Circle No. 90, Page 217, for more data

Power Driveshaft 91

transmits torque up to 1650 lb-in. at 440 rpm

Extra heavy-duty flexible power driveshaft has a 1¼-in. diameter core composed of layers of tightly wound, high grade music wire. The shaft can transmit up to 1650 lb-in. of torque at 440 rpm. The shaft casing is lined with oil-tempered spring steel, reinforced with wire braid and covered with oil-resistant Neoprene impregnated fabric and



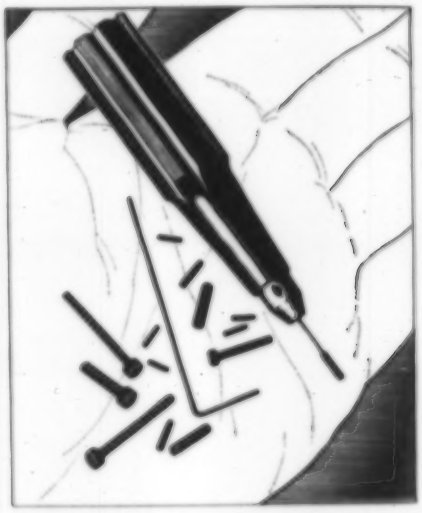
an abrasion resistant rubber jacket. The casing serves as the bearing surface for the core and also retains the lubricant. Extra reinforcement can be added to one end of the shaft, as shown at the top of the illustration. Lower view shows the heavy-duty core pulled out of the casing slightly and illustrates the steel-backed bronze sleeve bearing. Bearings are provided at each end to permit the core to float inside the casing. Couplings of various bores are available for connecting at each end. For applications which might require a change in the length of the drive, square slip joints 18 in. long are available for connection at one end. Made by **Stow Mfg. Co.**, 11 Shear St., Binghamton, N. Y.

Circle No. 91, Page 217, for more data

Miniature Screws 92

high-strength, hex-socket type

Line of miniature hex-socket capscrews and setscrews, in diameters of No. 0 through No. 3, are made in ⅛ to ½-in. lengths. Setscrews are offered with both coarse and fine threads, except No. 0 and No.



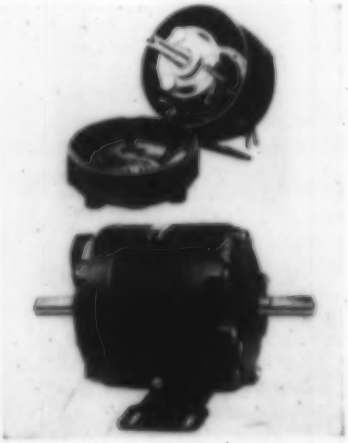
1 diameters, which are standard in fine series only. These minicaps and minisets are for use in a wide variety of small devices, instruments, radio equipment, meters, cameras and electronic and x-ray tubes. High-strength screws have extremely close tolerances and socket uniformity. They will hold to the key or driver for easy starting. Capscrews have knurled heads. Made by **Allen Mfg. Co.**, 133 Sheldon St., Hartford 2, Conn.

Circle No. 92, Page 217, for more data

Centrifugal Switches 93

furnished in packaged units

Compact Syncro-Snap speed regulation units are available in types for continuous, automatic speed regulation over a narrow speed band; as a governor control of dual, predetermined minimum/maximum speeds over a greater speed band; or to govern a single high speed or a single low speed. The controls can utilize up to three



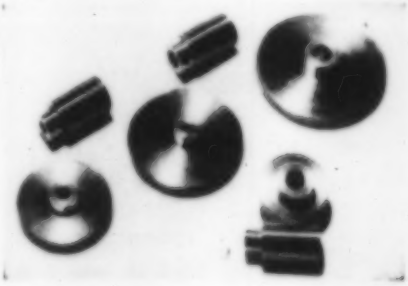
independent governors for control of multiple or interrelated circuits. They can be mounted vertically or horizontally, to detect or control speed on almost any device or equipment utilizing rotary motion. Rotational speed is detected independently of voltage or load. The control operates with positive nonfluttering snap action at the instant of cut-in or cut-out. Fractional speed can be regulated by the use of gearing, and preset speeds can be varied by the user up to 10 per cent by means of an adjustment screw on the housing. Controls are built in three sizes, can have open, closed or explosionproof housings and can be flange or foot-mounted. Made by **Torq Engineered Products Inc.**, 34 Interstate St., Bedford, O.

Circle No. 93, Page 217, for more data

Worms and Gears 94

precision made in small shaft sizes

Right - hand precision ground worms, made of No. 303 stainless steel, are available in single, double and four-thread types. Bronze



gears designed to run with these worms are available with from 60 to 120 teeth. Both worms and gears are available in basic shaft sizes of $\frac{1}{8}$, $\frac{3}{16}$ and $\frac{1}{4}$-in. diameter. Made by **PIC Design Corp.**, 160 Atlantic Ave., Lynbrook, L. I., N. Y.

Circle No. 94, Page 217, for more data

Sequence Valves 95

operate with low leakage and low pressure drop

Built for 3000-psi hydraulic service, standard models of these slide type sequence valves have a maximum internal leakage rate of 15 drops per minute. Special models are available with maximum leak-

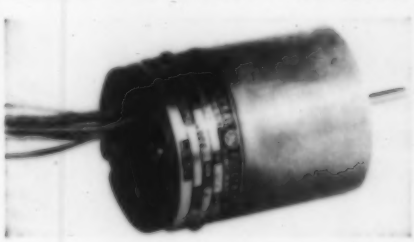
age of 5 drops per minute. Design incorporates a balanced self-cleaning spool which is selectively lapped into a rigid sleeve. Spool design provides low pressure drop. The valves are furnished with AND - 10050-4 or AND - 10050-6 ports for $\frac{1}{4}$ or $\frac{3}{8}$-in. tube sizes and are provided with either full flow by-pass or thermal type auxiliary relief valves for use at cracking pressures from 8 to 4000 psi. Standard models operate at ambient temperatures ranging from −65 to 275 F. Actuated by either plungers or levers, they provide flow in either direction from pressure port to outlet port when plunger is depressed. When the plunger is extended, flow is blocked from outlet port to pressure port. Made by **Aircraft Products Co.**, 300 Church Rd., Bridgeport, Pa.

Circle No. 95, Page 217, for more data

Miniature Servo Motor 96

withstands 1500 v

This dc servo motor is capable of withstanding a high potential of 1500 v and of responding to field currents of 0.0075-amp. Suitable for use in aircraft on blowers, actuators, tuners and similar devices, it will operate at sea level or at 50,000 ft and within temperature limits of −65 to 165 F. The motor



is reversed by a double-pole, double-throw relay and is operated by separate excitation of the armature and differentially wound shunt

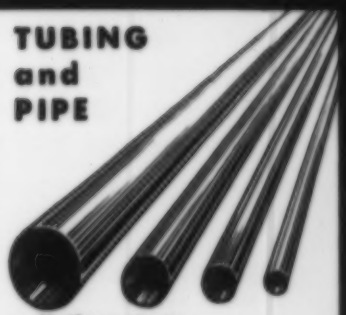
TOUGHEST DESIGN PROBLEM TO SOLVE . . .

Quality

SELECT WALLINGFORD STAINLESS STEEL STRIP

- Thinnesses To .002"
- Accuracy To ±.0001"
- Special Sections Rolled To Your Exact Design

TUBING and PIPE



- Uniform Walls
- High Heat and Corrosion Resistance
- Unusual Strength and Wear Resistance

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THE WALLINGFORD STEEL CO.

WALLINGFORD, CONN., U.S.A.

STAINLESS • ALLOY HIGH CARBON LOW CARBON • STRIP STAINLESS WELDED TUBES AND PIPE

for TOUGHNESS
WEAR RESISTANCE
IMPACT

specify AMSCO®
MANGANESE STEEL

- nonmagnetic
- resists impact
- high strength
- work-hardens
- resists abrasion
- high ductility
- slow crack propagation
- low temperature toughness

Manganese steel actually *absorbs energy.* Impact work-hardens the surface of the metal to as high as 550 BHN, while below the surface it maintains its ductility. Roughest abrasion only polishes this versatile metal.

Another highly desirable feature is manganese steel's slow crack propagation rate. This is a built-in safety factor, allowing early discovery of impending failure so that remedial action can be taken before costly damage or breakdown occurs.

Amsco manganese steel, being an austenitic structure, remains tough at low temperatures, retaining a valuable safety factor even at cold −100°F.

All of its characteristics, including a complete discussion of its technical aspects and inherent design features are contained in the Amsco booklet, *Austenitic Manganese Steel.* It's free. Send for your copy today.

AMERICAN Brake Shoe COMPANY

AMERICAN MANGANESE STEEL DIVISION
Chicago Heights, Illinois

New Parts

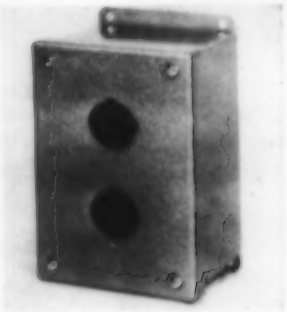
fields, the signal differential between the field structures being utilized as its control. It draws maximum armature current of 0.8-amp from a 28-v line, is rated at 0.002-hp at 6500 rpm and can be geared to speeds as low as 130 rpm. Weight of the motor is under 8 oz. Made by **General Electric Co.**, Specialty Component Motor Dept., Schenectady 5, N. Y.

Circle No. 96, Page 217, for more data

Pushbutton Enclosures 97

oil-tight units in ten sizes

Fabricated from 14-gage steel, these oil-tight pushbutton enclosures are available in sizes for 1, 2, 3, 4, 6, 9, 12, 16, 20 and 25 control units. Cover with sponge neoprene gasket is fastened to the box by four nickel-plated captive screws which thread into closed tapped holes located in box flange.



Cover is hinged to permit removal or opening for wiring of control units. Button openings are on 2¼-in. centers. External mounting feet can be used in any position, vertical or horizontal. Finish is gray hammertone baked enamel over phosphatized surface. Made by **Hoffman Engineering Corp.**, 1217 Tyler St., Anoka, Minn.

Circle No. 97, Page 217, for more data

Indexing Tables 98

capable of up to 300 indexes per minute

Designed for use in limited space, two indexing dial feed tables have 7¼-in. diameter plates; 10-in. plates are optional. The tables will not over-ride and are capable of up to 300 indexes per minute with a 40-lb load. They can be set for 4, 6, 8, 12, or 24 indexes per

only

CLEARPRINT
Tracing Paper

does so many things so well!

For the perfect working surface, for ghost-free prints, for proven stability - Clearprint Technical Paper has no equal. Since its introduction in 1932, other paper makers have strived to duplicate Clearprint's quality. None has succeeded. Your drawings deserve this superior paper. Insist on genuine Clearprint, *watermarked* for your protection.

THERE'S A CLEARPRINT PAPER FOR EVERY JOB

Tracing Paper · "Papercloth"
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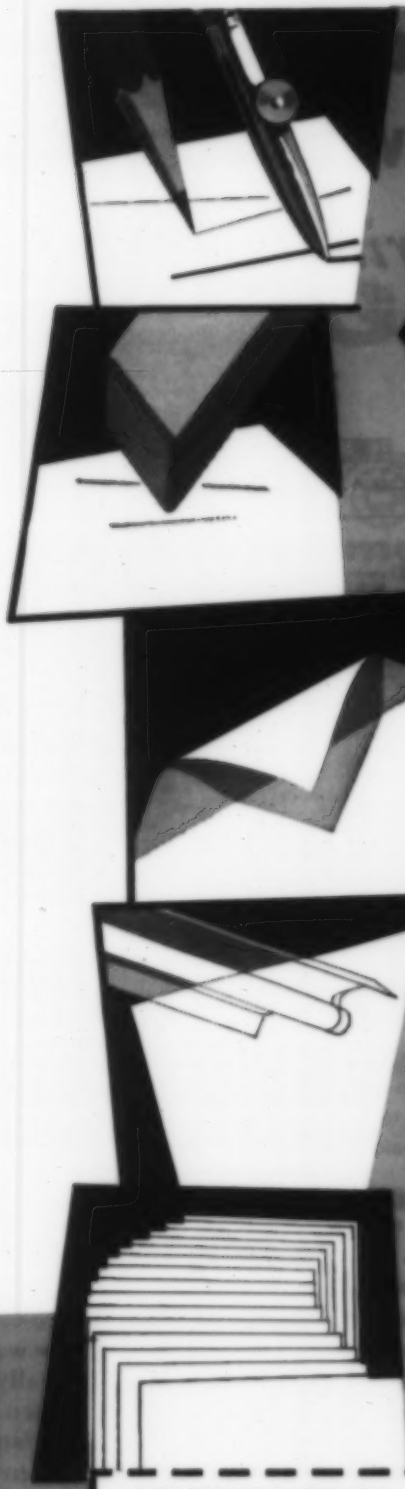
Federal Aid Sheets
"Fade-Out" Grid Paper

IN SHEETS, PADS and ROLLS



YOU BE THE JUDGE...

Make this simple

CLEARPRINT TEST

1. INVITES PENCIL AND PEN —

Try Clearprint's perfect working surface with a 2H pencil, then with a ruling pen. Lines are sharp and clean — no feathery edges.

2. NO GHOSTING —

Erase some of the lines. Redraw and erase several of them repeatedly. Crease the paper, too. Then hold it to the light, or make a reproduction. Seeing is believing!

3. NEVER CHANGES —

Sheets in use since 1932 prove Clearprint does not tear or become "dog-eared" in the files. Its strength, transparency and printing qualities remain unchanged after extended exposure to age, atmosphere, heat and light.

Make this test, too, on the paper you are now using. The difference will convince you.

CLEARPRINT®

TECHNICAL PAPER

THERE IS NO SUBSTITUTE
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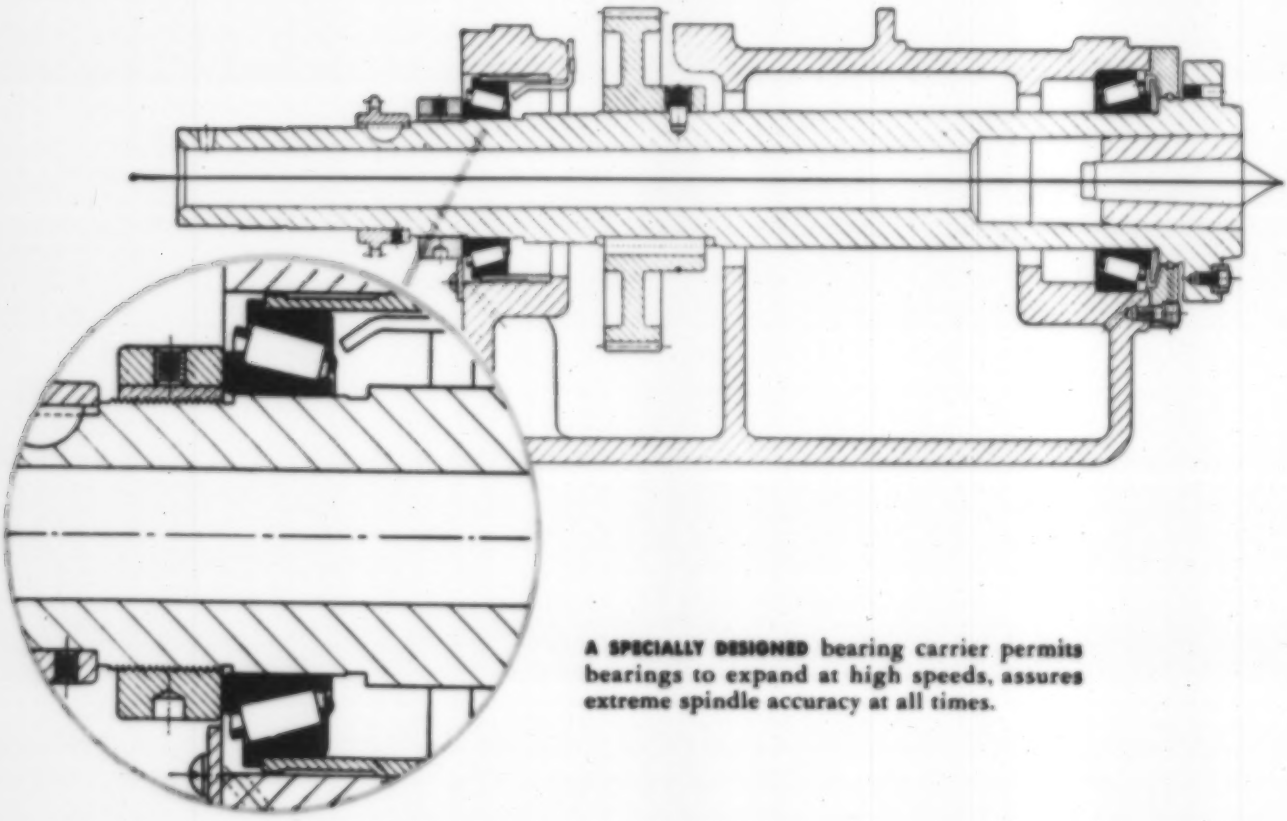
How to maintain extreme spindle precision from low to very high speeds:

TIMKEN® bearings with semi-flexible mounting



A SPECIALLY DESIGNED bearing carrier permits bearings to expand at high speeds, assures extreme spindle accuracy at all times.

THE Timken Company has an ingenious solution to the problem of maintaining a high degree of spindle precision in machine tools. At high speeds, bearings expand. Normally this would cause the bearings in a precision mounting to tighten up and become excessively preloaded. But engineers at the Timken Company have developed a semi-flexible mounting. The rear spindle bearing is mounted in a special carrier. The carrier is designed to permit the rear bearing to expand radially while the entire spindle assembly expands longitudinally. As a result the desired bearing setting is maintained under all operating speeds. Extreme spindle accuracy is maintained at all times.

Timken® tapered roller bearings with these mountings have been applied to the spindles of many types of machine tools with great success. Of course not all machine tool spindles are required to operate at high speeds and over a variable range of speeds. The conventional Timken spindle mounting is entirely adequate for most machines.

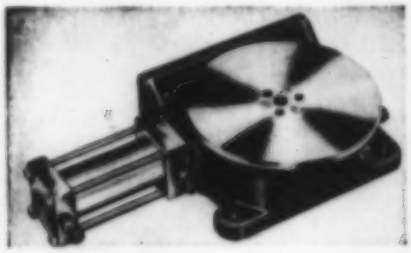
Whatever your requirements, there are Timken tapered roller bearings to meet them. If not we'll find a new way, as we did when machine tool builders originally asked for precision bearings. And as we did when they asked for greater accuracy, which led to the famed Timken "O" and "OO" bearings. The Timken Roller Bearing Company, Canton 6, Ohio. Canadian plant: St. Thomas, Ontario. Cable address: "TIMROSCO".

TIMKEN

TRADE-MARK REG. U. S. PAT. OFF.

TAPERED ROLLER BEARINGS

NOT JUST A BALL ○ NOT JUST A ROLLER ▭ THE TIMKEN TAPERED ROLLER ▭ BEARING TAKES RADIAL ◫ AND THRUST ◫ LOADS OR ANY COMBINATION ◫



revolution. Special indexes are available on order. Mounting is provided for either horizontal or vertical application. Compressed air is available through the center stud for actuating secondary equipment. Model 725-EA is furnished without control valves and model 725-EB is equipped for automatic operation and has controls regulating dwell time and forward motion. Made by **A. K. Allen Co., 57 Meserole Ave., Brooklyn 22, N. Y.**

Circle No. 98, Page 217, for more data

Miniature Control Valve 99

for hazardous process flows

Bantam bellows-sealed diaphragm control valve has bellows rating of 500 psi within the range of −70 to 700 F. No. 2038 unit shown has special flange facing to receive

½-in., 150-lb ASA raised face flange. Action is air-to-close. The valve has a Teflon seat with extra Teflon packing above the bellows. Maximum diaphragm pressure rating is 100 psi. Body and bonnet assembly are stainless steel. Leakproof, the valve is designed for control of hazardous process flows. Air cooling fins or extended neck bonnets can be supplied. Angle and offset types are available with

(*Continued on Page* 260)

DESIGNERS

send us your telephone number ...it may mean a better future for you!

Because of increased emphasis on some of our long-range projects, we want to establish immediate contact with competent designers.

To those who qualify, we can offer a real opportunity to build solid, well-rewarded careers.

If you want a chance to grow, attractive wage rates, extra benefits, New England living — mail this coupon today!

Particularly important is your telephone number. We may want to call you at once to arrange for personal interviews or plant visits.

Mr. P. R. Smith
Dept. 4, Design Employment
Pratt & Whitney Aircraft
East Hartford 8, Conn.

I would like to learn more about your openings for product and component designers. My experience has been in the following fields:

☐ Nuclear Design ☐ Aerodynamics ☐ Bearings
☐ Compressors ☐ Hydraulics ☐ Piping
☐ Turbines ☐ Gears ☐ Controls
☐ Structures ☐ Valves ☐ Test Equipment
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Total years Mechanical Design experience .....

You can reach me at ..... (telephone number) Most convenient hours for receiving calls are between ..... and .....

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Mail this coupon TODAY!

PRATT & WHITNEY AIRCRAFT

Division of United Aircraft Corporation

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World's foremost designer and builder of aircraft engines

AJAX announces

New 3-D Degree DIHEDRAL COUPLINGS

THE FIRST TRULY

New Ajax 3-D Dihedral Couplings handle up to 3 degrees of misalignment. They are priced at the same level as ordinary gear type couplings!

These new Ajax 3-D Dihedral Couplings now make it possible for design engineers to take advantage of Dihedral performance at low first cost. Precision assembly tolerances can often be relaxed, with savings at the factory and in the field.

The exclusive Ajax Dihedral principle has been proved and approved under the most severe operating conditions.

Features of the new Ajax 3-D Dihedral Coupling include:

3 degree misalignment capacity.

Load is distributed at center of teeth at the point of greatest strength.

More tooth strength is provided under misalignment than is possible with any other tooth shape.

Exclusive Ajax Dihedral tooth design has less clearance than conventional gear type couplings.

No end-of-tooth wear under misalignment.

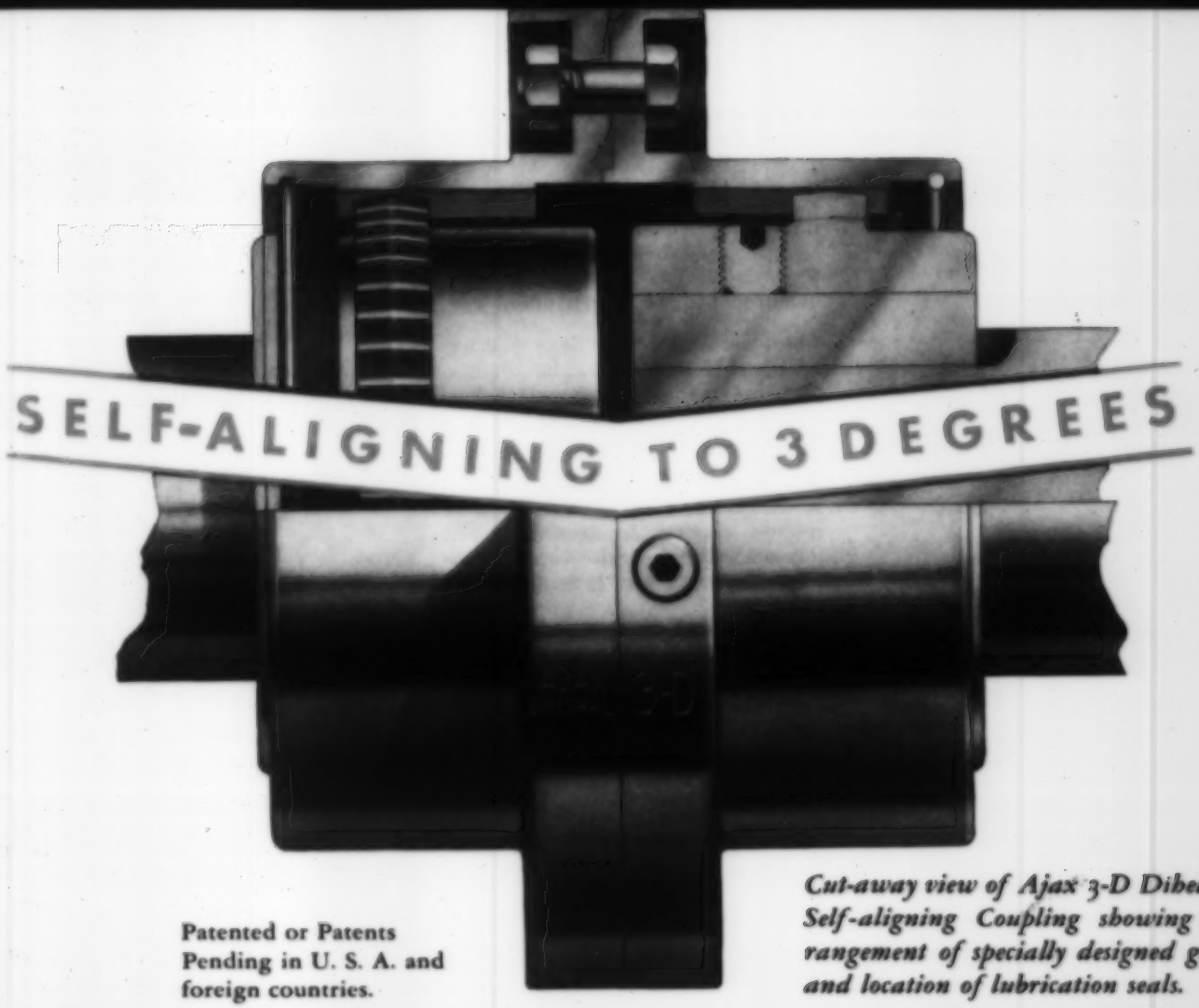
Johns-Manville "Clipper" seals keep lubricant in and foreign matter out.

Compact overall size.

Designed for NEMA motors with standard keys.

Low prices competitive with ordinary gear type couplings.

Available in 5 sizes.
Write for new Catalog No. 60.



Patented or Patents Pending in U. S. A. and foreign countries.

Cut-away view of Ajax 3-D Dihedral Self-aligning Coupling showing arrangement of specially designed gears and location of lubrication seals.

SELF-ALIGNING COUPLING

AT ORDINARY GEAR TYPE PRICES!!

AJAX FLEXIBLE COUPLING CO. INC.

REPRESENTATIVES IN PRINCIPAL CITIES

WESTFIELD, N. Y.

THE WORLD'S MOST COMPLETE LINE OF FLEXIBLE COUPLINGS

Performing Seal!

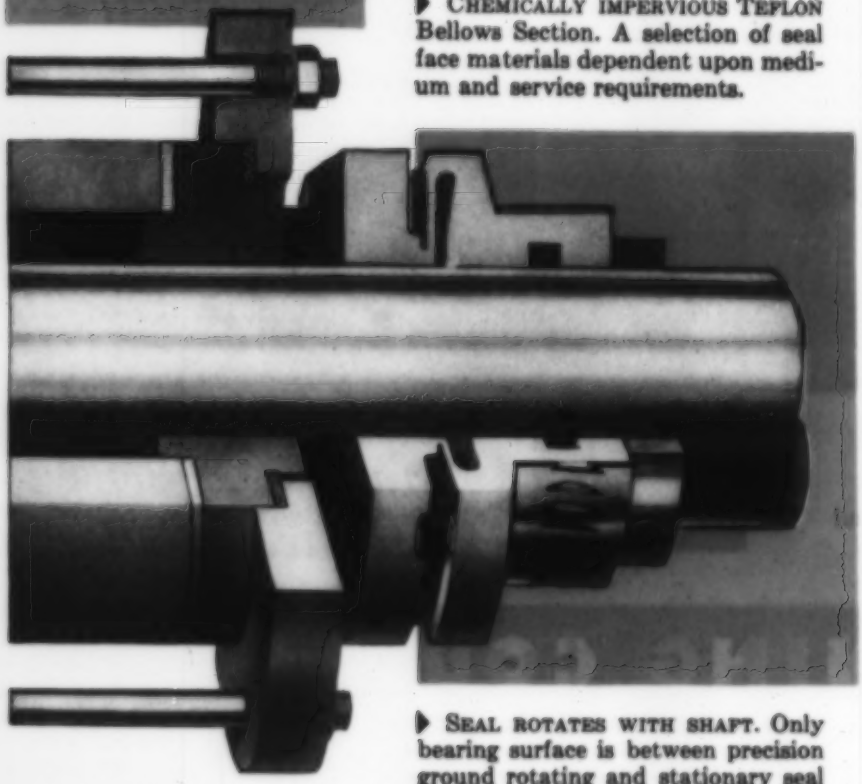
Service that no other Mechanical Seal can match

Pump difficult chemicals...with drop-tight service over longer periods of time. That is what Chemiseal's chemically impervious TEFLON, pressure-balanced bellows design offers you.

The ideal Mechanical Seal that has no equal in handling acids, alkalies, solvents, hydrocarbons, alcohols—clear liquids, slurries and tarry materials.

FEATURES

- CHEMICALLY IMPERVIOUS TEFLON Bellows Section. A selection of seal face materials dependent upon medium and service requirements.



- SEAL ROTATES WITH SHAFT. Only bearing surface is between precision ground rotating and stationary seal faces. Low friction load on shaft. Lower power cost. Drop tight service.
- NO SCORING OF SHAFTS and Chemiseals work satisfactorily on shafts previously scored by other seals or packing.
- PRESSURES at the seal up to 100 psi at 75°C or 75 psi at 100°C.
- SIZES from ¼" to 2¼". Other sizes for special applications.
- MAXIMUM LENGTH, all seals 2¼".

Write for Bulletin No. MS-954.

made of du Pont TEFLON

UNITED STATES GASKET COMPANY, CAMDEN 1, NEW JERSEY

USG FABRICATORS OF FLUOROCARBONS & OTHER PLASTICS

Representatives in principal cities throughout the world

New Parts

(Continued from Page 257)

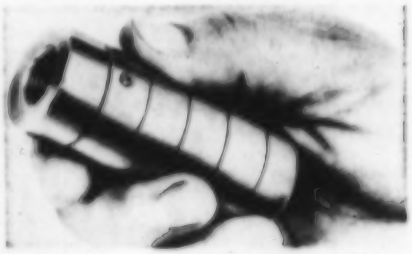
welding, screwed or flanged ends. Made by **George W. Dahl Co. Inc.**, 430 High St., Bristol, R. I.

Circle No. 99, Page 217, for more data

Pneumatic Silencers 100

dampen noise without reducing operating efficiency

Quietaire silencers reduce sound to 75 decibels, the level found in the average factory. The silencers do not reduce the operating efficiency of machinery in which they are



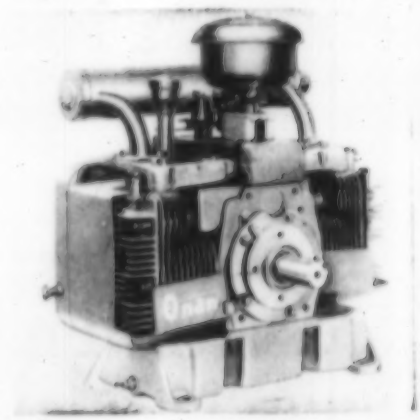
used. They are made of corrosion-resistant metal and can be used safely for any pressure normally encountered in industrial pneumatic service. Four models, in pipe sizes from ⅜ to 1 in., fit most industrial air operated equipment. Made by **C. W. Morris Co.**, 10628 Cloverdale, Detroit 4, Mich.

Circle No. 100, Page 217, for more data

Air-Cooled Engine 101

rated at 12.9 hp

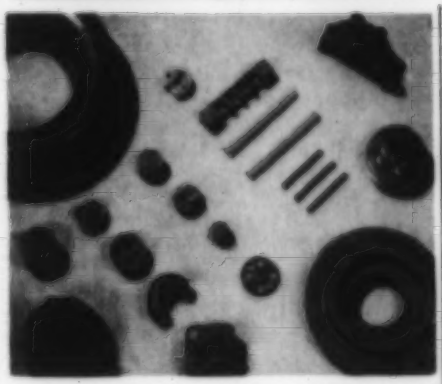
Compact two-cylinder, four-cycle model CCK gasoline engine is rated at 12.9 hp at 2700 rpm. It is of horizontally-opposed design and has 3¼-in. bore, 3-in. stroke and 50-cu in. piston displacement. The compression ratio is 5.5:1. Piston speed is 1350 fpm at 2700 rpm. The engine is manually started by



DOW CORNING CORPORATION

Silicone News

FOR DESIGN ENGINEERS



New Silicone Molding Compound Offered For High Temp Parts

Dow Corning 301 Molding Compound is a new glass-filled silicone compound developed for molding plastic parts which will withstand continuous exposure to 450 F and intermittent exposures to temperatures of 700 F and higher.

Typical properties of 301 fabrications after molding for 10 minutes at 340 F include: tensile strength of 5,000 to 7,000 psi; compressive strength of 10,000 to 12,000 psi and impact strength of 15 to 22 footpounds per inch. Flexural strength ranges from 12,000 to 14,000 psi at room temperature and 5,000 psi at 392 F.

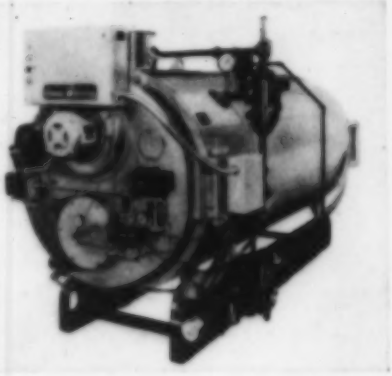
These properties suggest the use of 301 Molding Compound for a wide variety of high temperatures structural or dielectric parts for aircraft, electrical and electronic equipment. The new compound may be molded with conventional equipment by either compression or transfer techniques. Parts may be pulled hot without cooling, and after-baking is unnecessary except where the parts are to carry a load at high temperatures. Mold shrinkage ranges from zero to 0.0035 percent. Finished parts may be machined with high speed tools. *No. 54*

Silicone products most widely used, are indexed by type of application, in the 1955 Reference Guide to Dow Corning Silicone Products. A brief but comprehensive 8-page summary is given of the properties and applications. With increasing effort devoted to product improvement and cost reduction, such a reference guide to this remarkably stable group of engineering materials becomes increasingly important to design engineers. *No. 57*

Steam Boiler Manufacturer Finds Silicone Finishes More Durable

New silicone-based paints give more durable surface protection; air dry rapidly and cure in service to reduce the cost of finishing steam boilers made by the Cleaver-Brooks Company of Milwaukee.

Even the best organic finishes quickly failed and peeled at the normal operating temperatures of Cleaver-Brooks new "CB" line of 15-150 hp, 15-250 psi self-contained boilers. Vitreous enamels were more satisfactory but were much more expensive; required curing at 1200 to 1700 F; and being brittle, were easily cracked.



The solution came in the form of a new modified silicone finish developed by Midland Industrial Finishes. This coating shows no discoloration at temperatures in the range of 600 F, far above the hottest skin temperatures of the boiler.

Only one coat is required. Sprayed on, it air-dries tack-free as quickly as lacquer; cures later, when the boiler is in actual service; and retains its orginal attractiveness and protective qualities for the life of the unit. The new finish is available in a variety of colors. "CB" boilers are finished in grey with maroon frames. Cleaver-Brooks report, "the silicone paint provided the best solution we could find to our particular problem." *No. 55*

Silastic, the Dow Corning silicone rubber, keeps its shape, stays resilient from —100 to 500 F; resists hot oils and chemicals; withstands weathering ozone and corona; and is an ideal dielectric material. Properties of Silastic are fully detailed in new reference brochure. *No. 58*

Clamps Lined With Silastic Simplify Jet Engine Assembly

In building the B-52, B-47 and KC-135, Boeing cuts assembly costs and protects tubes and wires against wear due to vibration by attaching them to the engines with clamps cushioned with Silastic®, the heat-stable Dow Corning silicone rubber.

The Silastic liners in these new clamps made by General Metals Corporation, Adel Division, Huntington, West Va., remain resilient even after long exposure to temperatures ranging from —90 to 600 F. They also show high resistance to moisture, ozone and hot oils.

Dielectric strength tests show that these liners retain good dielectric properties for 7 minutes while a flame at 2000 F converts the Silastic to powdered silica. Under identical test conditions, comparable asbestos-lined clamps shorted out in 30 seconds or less.

Wires are quickly gathered into bundles and secured to the engine, saving the time previously required to make or disassemble bundles wrapped with tape. Clamps cushioned with Silastic more than justify their somewhat higher initial cost by savings in installation, maintenance and replacement costs. ®TM. REG. U.S. PAT. OFF. *No. 56*

Design Edition 14

DOW CORNING CORPORATION · Dept. 6811
Midland, Michigan

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ATLANTA · CHICAGO · CLEVELAND · DALLAS · DETROIT · LOS ANGELES · NEW YORK · WASHINGTON, D. C. (Silver Spring, Md.)
Canada: Dow Corning Silicones Ltd., Toronto; **Great Britain:** Midland Silicones Ltd., London; **France:** St. Gobain, Paris

U.S. Multi-Flex Boots travel tirelessly to protect moving parts

Longer travel ratios with far less fatigue is one of the many advantages obtained by United States Rubber Company's exclusive Multi-Flex® Boots. Accordion-like in action, the boots compress or extend without stretch or strain of the wall structure. Protective boots of rubber, or rubber and fabric circumferentially corrugated, are made by this process without the use of molds. Multi-Flex Boots are particularly economical for smaller runs.

On hundreds of widely varying installations, Multi-Flex Boots have simplified the equipment designer's task. They do many protective jobs conventional boots will not do. Their small outside diameter permits their use where space is limited. Multi-Flex Boots will meet travel requirements unobtainable in conventional boots. They are available in Inside Diameters from ¼" to 36" and in Silicone-Fiberglas construction for service in a temperature range of minus 65° to 500°F.

Any maker of equipment with moving parts which needs protection should investigate U. S. Multi-Flex. For engineering advice, get in touch with any of our 27 District Sales Offices, or write to address below for a free copy of our Multi-Flex Catalog.

"U.S." Research perfects it.
"U.S." Production builds it.
U.S. Industry depends on it.

US RUBBER

UNITED STATES RUBBER COMPANY

MECHANICAL GOODS DIVISION · ROCKEFELLER CENTER, NEW YORK 20, N. Y.

Hose • Belting • Expansion Joints • Rubber-to-metal Products • Oil Field Specialties • Plastic Pipe and Fittings • Grinding Wheels • Packings • Tapes Molded and Extruded Rubber and Plastic Products • Protective Linings and Coatings • Conductive Rubber • Adhesives • Roll Coverings • Mats and Matting

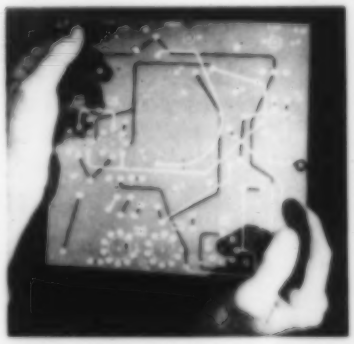
means of a pull rope; however, a recoil starter is available as optional equipment. Size of the engine is 19½ in. wide, 17⅞ in. high and 14¾ in. deep. Typical applications include refrigeration units, air compressors, construction equipment and farm implements. Made by **D. W. Onan & Sons Inc.**, University Ave., S.E., at 25th Ave., Minneapolis, Minn.

Circle No. 101, Page 217, for more data

Laminated Plastic 102

cold-punching type for printed circuitry

Possessing characteristics which make it suitable for use in printed circuits as well as other applications, Formica XXXP-36 paper-base phenolic impregnated sheet is translucent to a degree that permits a visual check on the accuracy of printed circuit register. The



material also provides high accuracy in printed circuitry and offers 1 million megohms insulation resistance. Other properties include high dielectric strength, high heat resistance and good bonding strength. The laminate can be cold punched in thicknesses to 1/16-in. Made by **Formica Co.**, 4614 Spring Grove Ave., Cincinnati 32, O.

Circle No. 102, Page 217, for more data

Steam Trap 103

inverted bucket type retains prime

High discharge capacity in small type B inverted bucket steam trap is made possible by the use of large valves operated by Camlift valve mechanism, which provides the force needed to open the valves

(*Continued on Page* 266)

YOU NAME IT-

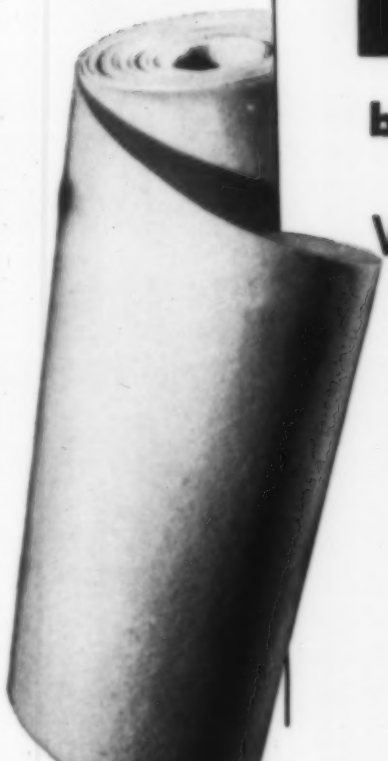
FELT

by FELTERS

will do it...

Filters
Auto parts
Washers
Noise dampeners
Wicks
Packings
Liners
Electrical appliances
Aircraft parts
Shock absorbers
Vibration controls

(Your product goes here)



Resiliency that permits constant spring-back to original shape . . . and good absorptive characteristics . . . are just two of the many properties you can get in Felt made by Felters.

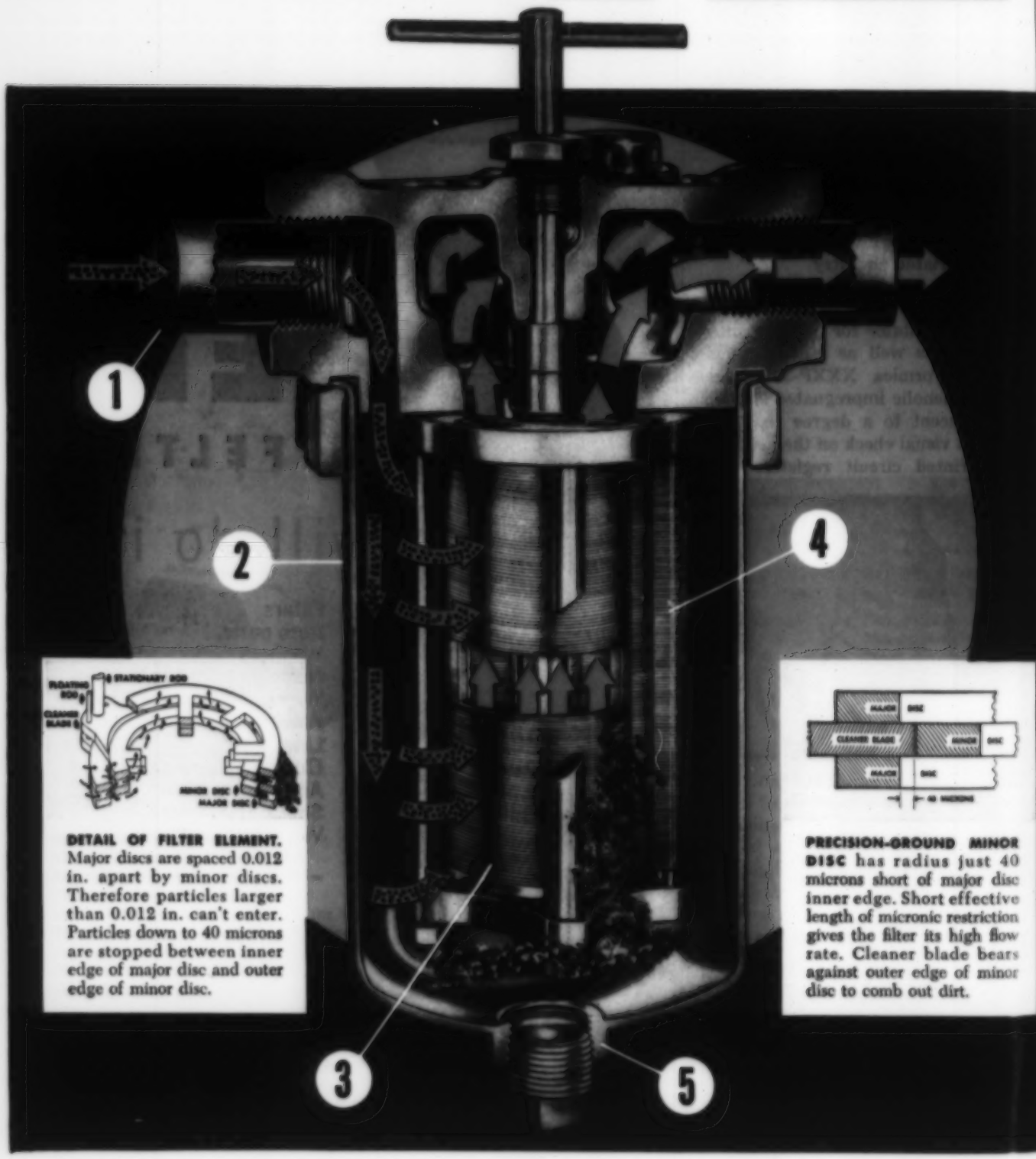
If you have a problem that could be solved by a soft, porous material, or by a hard, dense material — your answer could well be a Felt made by Felters.

The "Felters Design Book" describes several usual and unusual uses for Felt. Drop us a line and we will send you a copy.

HEARD ABOUT **UNISORB®** *— THE MODERN MACHINERY MOUNTING?*

The **FELTERS** Company
218 South Street, Boston 11, Mass.

New! CUNO 40-micron



DETAIL OF FILTER ELEMENT. Major discs are spaced 0.012 in. apart by minor discs. Therefore particles larger than 0.012 in. can't enter. Particles down to 40 microns are stopped between inner edge of major disc and outer edge of minor disc.

PRECISION-GROUND MINOR DISC has radius just 40 microns short of major disc inner edge. Short effective length of micronic restriction gives the filter its high flow rate. Cleaner blade bears against outer edge of minor disc to comb out dirt.

CUTAWAY of new SUPER Auto-Klean. Dirty liquid enters inlet (1) at left, fills housing (2) and flows through metal-edge filter (3) of stacked major and minor discs. Trapped dirt is combed out by cleaner blades (4) when discs are rotated and is removed through drain (5). Clean liquid rises through center of filter element, leaves at right.

self-cleaning filter!

The SUPER Auto-Klean for lube, hydraulic fluid, coolant, fuel and other liquids

. . . and you can clean this filter by simply turning the handle!

Many times smaller than other micronic filters of equal capacity, Cuno's new SUPER Auto-Klean filter now makes possible economical, compact, micronic filtration at high flow rates and eliminates the need for replacement cartridges. On machine tools and industrial machinery, SUPER Auto-Klean gives micronic filtration of lubricating oil, hydraulic fluids, coolants, fuels and other liquids. Here's what it offers:

1. Full-flow micronic filtering with a self-cleaning filter. Filter can be cleaned continuously with motor drive or intermittently by manually turning handle.

2. Eliminates cartridge changes. Ends operating costs if you've been using cartridge filters.

3. No pressure drop build-up. An 8-in. long, 2½-in. diameter cartridge handles 30 gpm of oil of 200 SSU viscosity with only 3 psi pressure drop—up to 75% more with slightly higher pressure drop.

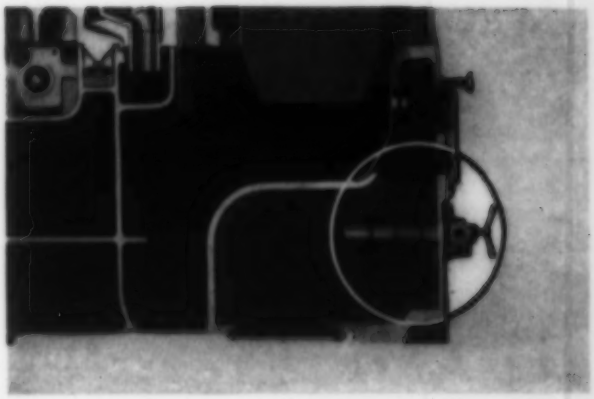
4. Positive protection against particles larger than 40 microns (actually 0.0015 in.). Filter can't rupture or channel.

5. Much smaller than replaceable-cartridge-type filters of equal capacity. It saves with lower initial costs, lower installation costs, requires less space than cartridge units. You get high capacity in a small package.

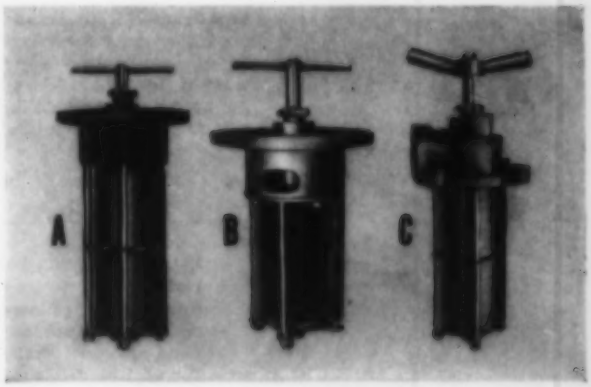
6. No duplex units needed. Handles full flow all the time with no interruptions for cleaning.

7. SUPER Auto-Klean fits existing Auto-Klean housings. You can easily replace most 2¾-in. diameter cartridges with SUPER Auto-Klean for finer filtration.

Send coupon for complete information on the new SUPER Auto-Klean filter, for your new designs or existing equipment. Cuno Engineering Corporation, 20-11 South Vine Street, Meriden, Conn. 5.6



WILL IT FIT? Here's how one designer answered that question. Filter *(circled)* mounts horizontally in side wall of hydraulic fluid reservoir in this surface grinder.



FILTERS FOR INTERNAL PIPING *(A and B above)* allow streamlined design plus the best in filtration. Flange mounting with external outlet *(C above)* and line-type *(cutaway on facing page)* are just two of many other possibilities.

MAIL COUPON FOR COMPLETE INFORMATION

CUNO

ENGINEERED FILTRATION

Removes More Sizes of Solids from More Kinds of Fluids

AUTO-KLEAN (disc-type) • MICRO-KLEAN (fibre cartridge)
FLO-KLEAN (wire-wound) • PORO-KLEAN (porous metal)

CUNO ENGINEERING CORPORATION
14-11 South Vine Street,
Meriden, Connecticut.

Please send me full data on the NEW Cuno SUPER Auto-Klean filter.

Name_____

Firm_____

Position_____

Address_____

City_____ **Zone**_____ **State**_____

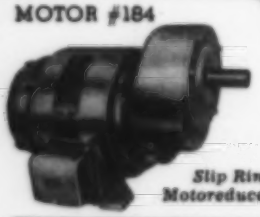
SAVE

on original development costs
by using REULAND ELECTRIC'S

SPECIAL-MOTOR "LIBRARY"

Over 900 Different
Electric Motors

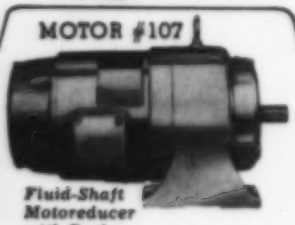
MOTOR #184



Slip Ring Motoreducer

HIGH STARTING TORQUE ON LOW CURRENT—plus variable speed reduction, are features of this Slip Ring Gear Reducer motor. Aids in getting heavy loads up to full speed through step by step starting.

MOTOR #107



Fluid-Shaft Motoreducer with Brake

FLUID-CUSHIONED ACCELERATION, SLOW SPEED, SPLIT-SECOND BRAKING—Internal fluid coupling provides smooth starts, prevents "jamming" of equipment. New "doughnut" magnetic brake can be mounted before or after coupling—or both.

MOTOR #841

Hydraulic Pump Mount Motor

MOUNT PUMP DIRECTLY TO MOTOR'S END BELL—Eliminates usual need for separate pump-mount platform. Insures absolutely perfect alignment with pump shaft. Available with flange on one or both ends. For all standard pump makes.

MOTOR #912

Right-Angle Worm Motoreducer

COMPACT SPEED REDUCER—This right-angle, worm type gear reducer provides lowest cost speed reduction. Mounts on floor, overhead or side. Extremely versatile, multi-shaft load hook-up. Fits tightest quarters.

REULAND'S "XPANDABLE" DESIGN MEANS ALMOST UNLIMITED ADAPTABILITY

Don't pay for special motor development until you first check the Reuland SPECIAL MOTOR LIBRARY. Reuland's revolutionary new XPANDABLE DESIGN idea has produced literally hundreds of unique power packages, one of which may already be the answer to your needs.

Reuland also produces a complete line of standard electric motors. Free engineering literature will be sent upon request. Your inquiry will be given prompt, personal attention.

REULAND ELECTRIC COMPANY
Distributors In All Principal Cities
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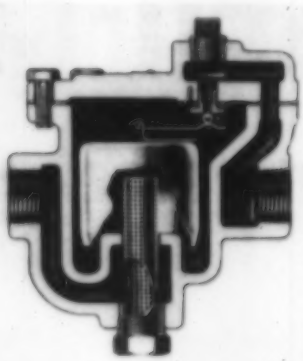
New Parts

(*Continued from Page 263*)



against steam pressure. Mechanism also provides quick opening to prevent partial water-logging of unit being drained. The trap retains its prime under such difficult operating conditions as light loads, rapid pressure drops and partial vacuum in the return line. Made by **Sarco Co. Inc.**, Empire State Bldg., New York 1, N. Y.

Circle No. 103, Page 217, for more data

Stainless Steel Wire 104

has lustrous finish

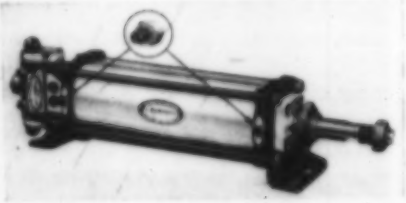
The natural, lustrous finish of a new stainless steel wire permits its use without plating or coating for many applications. The wire can be drawn in sizes from 0.030 to 0.090-in. and has a maximum tensile strength of 250,000 psi. It is available either coiled or in straight lengths. Made by **National-Standard Co.**, 601 N. Eighth St., Niles, Mich.

Circle No. 104, Page 217, for more data

Air Motor 105

has adjustable cushioning

Offered in all standard mounting styles, this 2½-in. bore air motor has adjustable cushioning at either or both ends. It operates at pressures up to 175 psi. Thrust is equal to five times air pressure applied. Unit has four-way valve and speed controls similar to oth-



Question about tubing?

ask your Rochester Products
Sales Engineer about
GM STEEL TUBING

GM STEEL TUBING BY ROCHESTER PRODUCTS, DIVISION OF GENERAL MOTORS, ROCHESTER, N.Y.

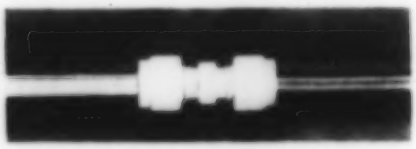
er Bellows air motors. The built-in valves are available for 8-v or 110-v momentary contact electrical control; 110, 220, 440, or 12-v maintained contact control; direct mechanical or manual control; air-pilot valve control; and air-poppet valve control. Cushioning is effective on final ¾-in. of stroke. Made by **Bellows Co.**, 230 W. Market St., Akron 9, O.

Circle No. 105, Page 217, for more data

Plastic Tube Fittings 106

eliminate galvanic action

Swagelok galvanic insulators, made of Du Pont Zytel polyamide resin, prevent galvanic action which results from joining dissimilar metals. Brass, aluminum, copper and



steel tubing can be joined. The fittings are available in a complete line of shapes and in 1/16 to 1-in. tube and pipe sizes. Made by **Crawford Fitting Co.**, 884 E. 140th St., Cleveland 10, O.

Circle No. 106, Page 217, for more data

Instrument Handles 107

are adjustable from 3¼ to 6 in.

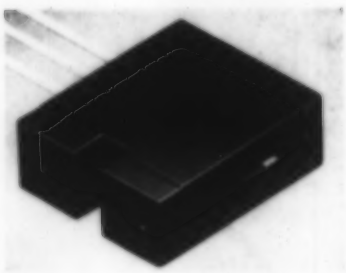
Center spacing of these handles is adjustable from 3¼ to 6 in. Any maximum center spacing can be furnished on order. Height of the handle above the panel can vary from 1 7/16 to 2 in. Standard handles are nickel-plated brass; others are available unplated or plated in any finish. They are available with or without ferrules and have 5/16-in. 18 thread. Handles are supplied with or without nuts and washers, as desired. Made by **U. S. Engineering Co. Inc.**, 521 Commercial St., Glendale 3, Calif.

Circle No. 107, Page 217, for more data

Read and Record Head 108

operates with high readback signal

Designed for low-cost recording or reading on magnetic drums in memory systems of digital computers, model MH 10-A read and record head operates with high readback signal and low noise and has high voltage insulation. It is potted and dimensionally stable. Precise machining of the mounting assures accurate alignment of the gap; the gap is square to the mounting surface and parallel to the drum axis. The mounting lends itself to the general purpose type drum where many heads are stacked, on drums having from 30 to several hundred channels. The writing or record current is less than 20 ma; readback voltage obtained is greater than 0.5-v peak-to-peak across 500 turns. Core width of the head is 0.040-in.; gap



width is 0.001-in.; number of turns is 250 each side of the center tap; and resonant frequency is over 500 kc. The unit is encapsulated in a die-cast aluminum case for moisture resistance, and it has a two-piece sintered core. Made by **Librascope Inc.**, 808 Western Ave., Glendale, Calif.

Circle No. 108, Page 217, for more data

Servo Motors 109

combine light weight with efficient cooling

Construction of new line of servo motors provides reduction in weight and increased cooling efficiency. Available in standard

WHEN IT'S
Special BOLTS
and STUDS
Send your Specifications to
ERIE
40 years' experience in making special bolts, studs, nuts for specific job requirements.

Specialists in Precision High Quality
CONNECTING ROD BOLTS

10
INTEGRATED COMPANIES
BARIUM
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MAGNESIUM, FIBERGLASS

REPRESENTATION IN PRINCIPAL CITIES

sizes 11, 15 and 18, as well as special sizes, the motors operate at ambient temperatures to 125 C. Power output can be increased in proportion to power input. Models are available for operation on 400 or 60-cycle current. Stators are embedded in an insulating compound of high dielectric strength and high temperature stability. The largest of the three motors, illustrated, is 1.75 in. in diameter. Made by **G-M Laboratories Inc.**, 4300 N. Knox Ave., Chicago 41, Ill.

Circle No. 109, Page 217, for more data

Lubricator 110

feeds oil to 25 bearing points

Cyclic type NV automatic lubricator will feed controlled amounts of oil to as many as 25 bearing points on small machines. Measuring 2 x 3 x 4¼ in., it is driven by the machinery it lubricates.

Drive is transmitted through a series of reduction gears to a piston type pump which discharges oil at 30 psi into a system of 5/32-in. tubing. Pump delivers 0.4-cc of oil per discharge from an 80-cc capacity reservoir. Four available sets of gears provide reduction ratios from 100:1 to 2¼ million to 1. A manually actuated instant feed button is provided. Made by **Bijur Lubricating Corp.**, 151 W. Passaic St., Rochelle Park, N. J.

Circle No. 110, Page 217, for more data

Solenoid Valve 111

for full 3000-psi service

Sizes of ½, ¾, 1, 1¼ and 1½ in. are available in model 6615 single-solenoid, pilot-operated hydraulic valve. Designed for 3000-psi service, this valve is of the subplate type for panel mounting, meets all JIC requirements and has rated capacity of 3.6 gpm at 15 fps. The solenoid operates on 3.6 amp inrush and 0.45 amp holding at 115 v. It has spring return and

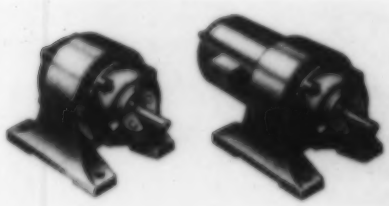
operates two-position on the four-way valve. Solenoid is used with the spool of the valve having all ports blocked in neutral. Made by **Rivett Lathe & Grinder Inc.**, Brighton 35, Boston, Mass.

Circle No. 111, Page 217, for more data

Adjustable-Speed Drives 112

use induction couplings

Stepless variable speeds over ranges from 2:1 to 34:1 with constant torque output, are provided by the MIC line of motor induction couplings. Drives feature fast response, maintain accurate speed and require minimum maintenance. Motor sizes range from ¾-hp at



500 Gears . . .

DOWN THE DRAIN

PRESIDENT, THE CINCINNATI GEAR CO.

We don't like to admit it, but we make our share of mistakes. Fortunately, these do not occur too often but when they do, we see to it that they do not reach you, our customer. Before any gear leaves our factory, it goes through a tough final inspection. Each of our highly trained inspectors checks the work as if he were the inspector in the customer's plant. These men answer only to me, thereby eliminating any possibility of influence that might be exerted by those interested only in production.

Recently when we were manufacturing a large order of bronze worm gears, a very serious error was inadvertently made during the manufacturing process. In spite of constant vigilance, this was not discovered until the gears reached final inspection. The boys sure found it at that time. Actually the error amounted to the fact that the teeth had been cut about .010 too deep. While it might have been possible to make the mating worms oversize, this thought was the farthest from our minds. Because the worm gears were NOT correct, they were scrapped and replaced. The loss resulted in one of the largest single scrapped orders that we ever had. It hurt.

We believe that our ardent will to supply gears of only the highest quality pays off. Our customers have the assurance that when they receive gears from CINCINNATI GEAR, these have been through a rigid and thorough inspection and are ready for assembly. Our men understand that there is "no compromise with quality," and that is the policy under which they operate. We also believe this is the least costly for our customers because once they receive our gears, they know there will be no "hidden" costs during assembly.

THE CINCINNATI GEAR CO.

CINCINNATI 27, OHIO

"Gears — Good Gears Only"

CINTI

Don't go daffy
looking for universal joints

asg
UNIVERSAL JOINTS
immediately available
from distributors stock

13
sizes with
bored or solid hubs

You can get ASG Universal Joints directly from stock in 13 sizes with bored or solid hubs ranging in diameter from .375" to 4.000". Special bores, bores with keyways or setscrews are available upon special order.

ASG Universal Joints are ruggedly constructed of heat treated alloy steel. Matching or mating parts are precision ground to permit easy interchangeability of components. Self-locking retaining rings on small pins simplify assembly and disassembly. Joint of ⅞" length and longer have snap ball oilers. Smaller joints have oil holes. Oil enters at center of rotation to assure thorough lubrication of moving parts.

Send today for Bulletin No. 527 describing the full line of A.S.G. Universal Joints available from your nearest distributor.

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PERFECTION GEAR COMPANY • HARVEY, ILL., U.S.A.

New Parts

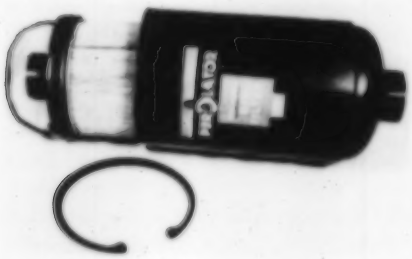
3400 rpm to 75 hp at 1700 rpm. Applications are in varying speed or controlling acceleration, deceleration and torque on loads requiring close speed regulation. Where loads fluctuate or input frequency varies, fixed and accurately controlled speed is insured by an automatic regulating device. When an existing motor is used, induction couplings are available as separate units. Made by **American Electric Motors Inc.**, 2112 Chico Ave., El Monte, Calif.

Circle No. 112, Page 217, for more data

Hydraulic Oil Filter 113

handles up to 75 gpm

Designed for hydraulic systems of large high-speed machine tools, this No. 56670 filter will trap micronic size particles in fluids under 1000-psi operating pressures. Unit can handle flow rates up to 75 gpm. Made of resin-impregnated paper, filter element is easily replaced by removing the snap ring holding the case cover in place. Steel case contains an O-ring seal in its head. Connections at both ends are 1½ in. Made by **Purolator Products Inc.**, Rahway, N. J.



Circle No. 113, Page 217, for more data

Limit Switch 114

controls two circuits

Suitable for a wide range of industrial applications where space is limited, the model 1LS1 heavy duty limit switch is designed for control of two independent circuits. Sealed switch has a roller arm actuator which is adjustable through 360 deg by the user and can be locked in any position. Actuation can be clockwise, counterclockwise or in both directions. The actuator head may face any

ANOTHER UNUSUAL PROBLEM SOLVED BY LORD...

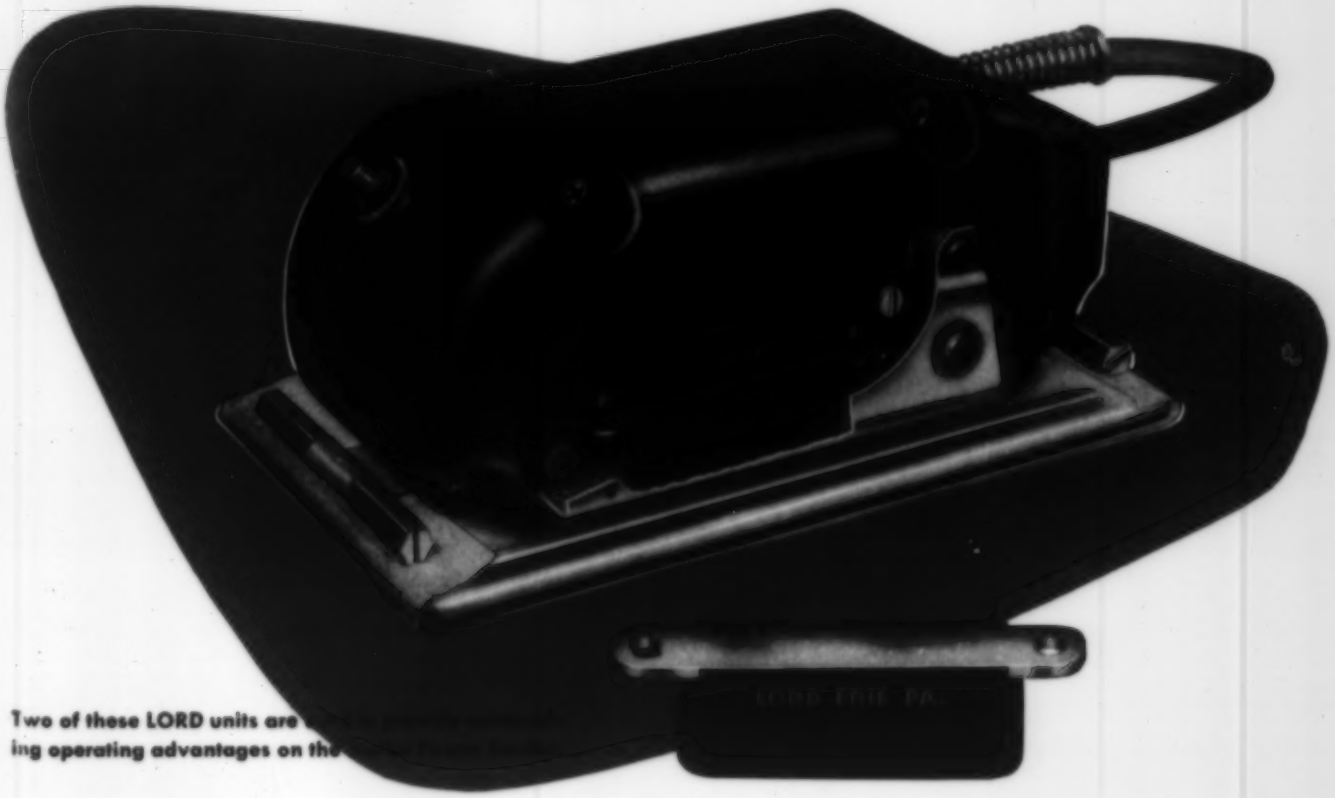
IMPROVED SANDING PERFORMANCE WITH LORD VIBRATION CONTROLS

The coordinated efforts of LORD development engineers and product engineers of the Weller Electric Company have resulted in several "built-in" performance advantages in the outstanding Weller Power Sander.

Lord Vibration Control units control the sanding plate action by (1) maintaining alignment of the plate to achieve straight-line motion, (2) eliminating vertical "bounce", and (3) transferring even pressure to all points of the sanding plate. In addition to these advantages, the flexibility of LORD units adds greatly to the service life of this sander by eliminating damaging rigid construction.

The LORD application on the Weller Sander is typical of many LORD contributions to better product performance through bonded-rubber vibration control units.

LORD is continually presenting new concepts in practical, efficient vibration control. Why not investigate the advantages LORD units will bring to your products? Simply contact the LORD Field Engineer nearest you or LORD MANUFACTURING COMPANY, ERIE, PENNSYLVANIA.



Two of these LORD units are ... ing operating advantages on th...

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CLEVELAND, OHIO · SUperior 1-3242 • DAYTON, OHIO · Michigan 8871
DETROIT, MICH. · TRinity 4-2060 • CHICAGO, ILL. · Michigan 2-6010
DALLAS, TEXAS · Riverside 3392 • LOS ANGELES, CAL. · HOllywood 4-7593
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LORD MANUFACTURING COMPANY • ERIE, PENNSYLVANIA

LORD
BONDED RUBBER

designers and producers of bonded rubber products since 1924

Design with these precision sprockets--

minutes less to install

LINK-BELT ROLLER CHAIN TAPER LOCK SPROCKETS bring new benefits

for the shop:

- **QUICK INSTALLATION.** Bushing and sprocket assembly slips easily into position on shaft. Setscrews draw sprocket onto taper bushing, causing bushing to clamp tightly on shaft — equivalent to a shrink fit.
- **NO REBORING DELAYS.** Bushings are stocked in bore increments of 1/16 in. for shaft sizes from 1/2 to 4-in. diameters. Sprockets mount with the tightness of a shrink fit.
- **BROAD RANGE OF SIZES.** Taper Lock Sprockets and matching Precision Steel Roller Chain are stocked in 8 pitch sizes, 1/2 to 2 in. — an ideal combination from one source.

NEW BOOK 2649 contains complete specifications. Link-Belt Roller Chain Taper Lock Sprockets are usually made of steel. Where size and weight are considerations, spoked cast iron sprockets are furnished.

For your copy or more information, call your Link-Belt Office.

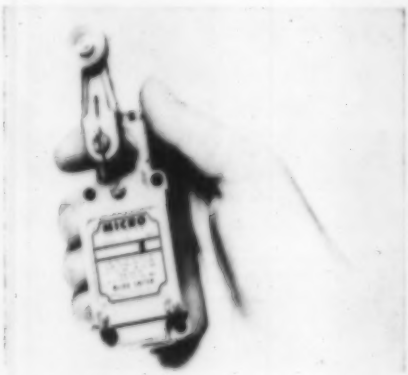
for the machine:

- **REMOVAL** is easily and quickly accomplished by using setscrew as jack screw in hole provided, which releases sprocket assembly from shaft with a few quick turns.
- **FULL BEARING, POSITIVE GRIP.** Full length of bushing supports sprocket on shaft. Tapered construction with uniform compression provides tightest, safest grip available.
- **NEAT APPEARANCE, SAFE, COMPACT.** Flush mounting requires minimum shaft space, and bushing requires no more room than sprocket hub. No projecting bolts or flanges.

LINK-BELT

ROLLER CHAIN AND SPROCKETS

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World.



of four positions at 90-deg angles. Contact arrangement is two-circuit, double-break. Electrical rating is 10 amp at 120, 240 or 480 v ac, and pilot duty rating is 0.2, 0.1 and 0.04-amp at 115, 230 and 550 v dc, respectively. Made by **Minneapolis-Honeywell Regulator Co.**, Micro Switch Div., Freeport, Ill.

Circle No. 114, Page 217, for more data

Stainless Tubing 115

in sizes to 2 1/16 in. OD

Types 304 and 321 Weldrawn welded and cold drawn stainless light-wall tubing are now available in sizes to 2 1/16 in. OD. Ultimately, this tubing will be made up to 2½ in. OD. Materials from which the tubing is fabricated are AISI types 304, 321 and 347 stainless steels and Monel metal. Minimum and maximum wall thicknesses for 1½ to 2 1/16-in. tubing are 0.010-in. and 0.025-in.; standard OD tolerances are +0.010-in., −0.000-in. Wall thickness tolerance is ±10 per cent. The tubing is made in lengths up to 28 ft by **Superior Tube Co.**, 1570 Germantown Ave., Norristown, Pa.

Circle No. 115, Page 217, for more data

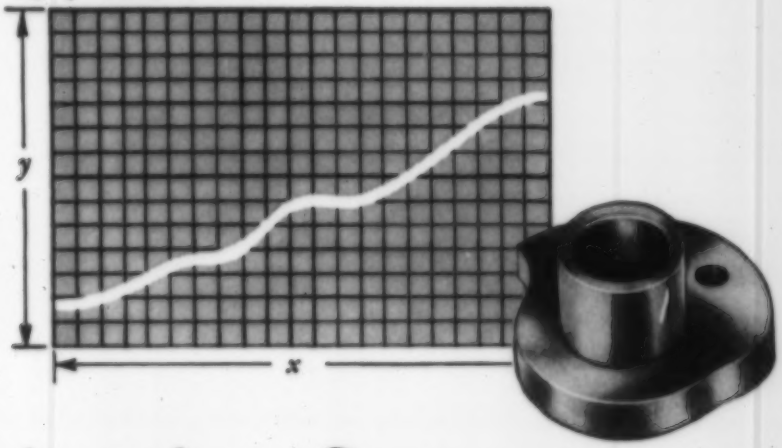
Solenoid Valve 116

does not require back pressure

Full port, normally closed type G solenoid valve does not require back pressure in its operation. It will operate and hold fully open with low or no flow pressure and is suited for use on vacuum lines and in control of liquids with wide range of viscosities. Temperature limit in latter application is 212 F, and static rating is 150 psi. Pack-

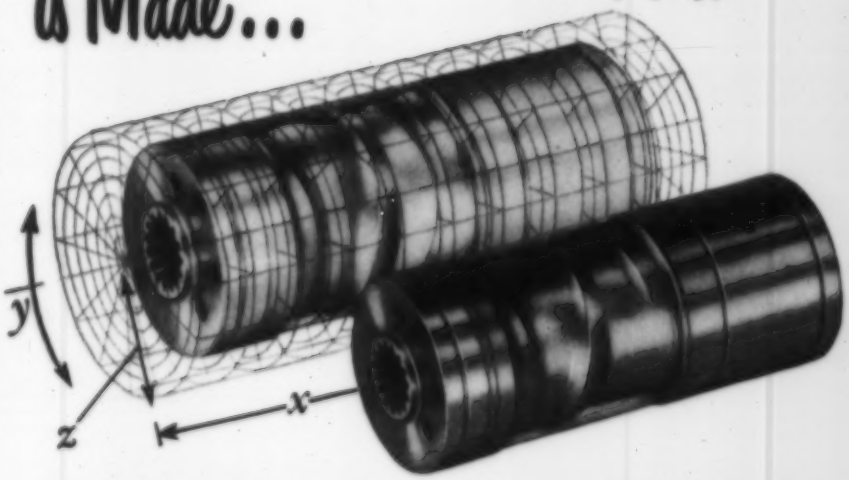
(*Continued on Page 278*)

Here's How a 2 Dimensional Cam is Made...



Here's How a 3 Dimensional Cam is Made...

$z = f(x,y)$



HERE'S HOW YOU CAN GET THE GRAPHIC STORY OF CAMS THAT "COULDN'T BE BUILT"—*BUT WERE DELIVERED BY PARKER!*

Send today for the new, fact-filled Parker folder—discover how Parker can engineer and build three dimensional cams with an infinite number of precisely machined stations to serve as the "brains" for a wide range of automatic operations.

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CAM DIVISION

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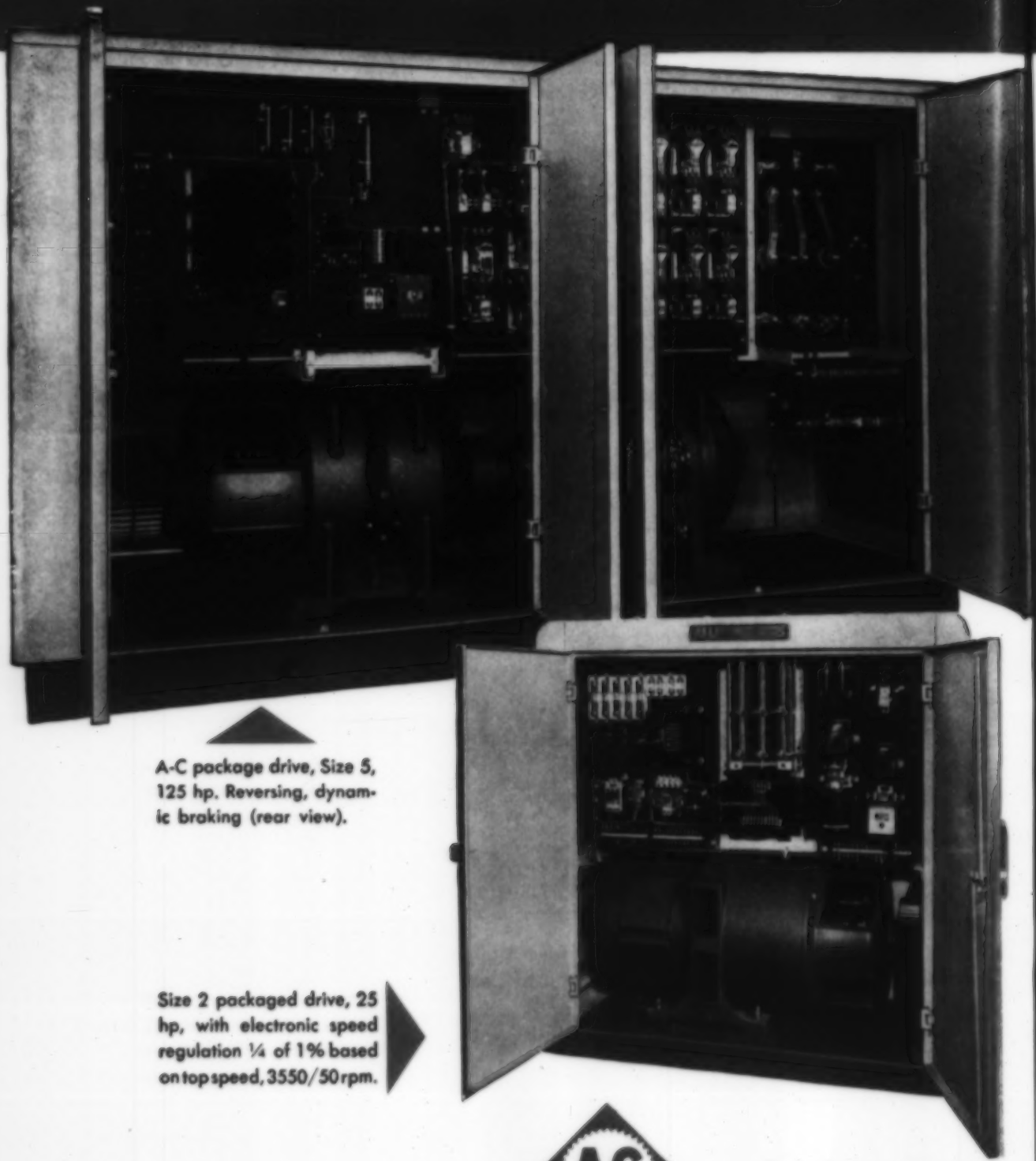
Get the Drive Tailored to Your Speed



A-C package drive, Size 5, 125 hp. Reversing, dynamic braking (rear view).

Size 2 packaged drive, 25 hp, with electronic speed regulation ¼ of 1% based on top speed, 3550/50 rpm.

A-C ALLIS-CHALMERS

ALLIS-

Control Needs

ALLIS-CHALMERS Package Drive Gives You

- ★ Wide speed range
- ★ Precise speed control
- ★ Operation from one or more points
- ★ Simple installation
- ★ Reduced maintenance

If you need speed control for up to 200 total horsepower plus special performance characteristics such as threading, jogging, dynamic braking, etc., the Allis-Chalmers package drive will provide these functions in one easy-to-specify unit. The package drive itself consists of a motor-generator set and control components mounted in a well-ventilated cabinet. Control stations and dc drive motors may be placed wherever convenient. Installation is simple because the unit is factory-wired and ready to operate. Maintenance is reduced because cabinet keeps equipment clean and out of harm's way. All three of the basic components — m-g set, control and drive motors — are designed to operate as a unit.

Engineering Assistance

Allis-Chalmers application engineers are thoroughly familiar with OEM problems and will be glad to help you at every stage of your operation. For help, call your nearby Allis-Chalmers District Office. For literature, write Allis-Chalmers, Milwaukee 1, Wisconsin. Ask for Bulletin 51B8166. A-4620

Vari-Pitch is an Allis-Chalmers trademark

Other Allis-Chalmers Speed Control Drives

Mechanical

Where a moderate speed range is required and where the machine may be stopped to make required speed changes. Horsepower range — 1½ to 300. Speed adjustment range — 9 to 28 percent. Two *Vari-Pitch* sheaves used together double range of adjustment.

Mechanical

Where speed must be changed while machine is in motion. Particularly good for machines requiring fine adjustment while operating. Double range of adjustment may be obtained by using two *Vari-Pitch* sheaves. Horsepower range—1½ to 600. Speed adjustment range —9 to 28 percent with one *Vari-Pitch* sheave.

Electrical

Where stepped speed control is satisfactory. Available with stepless control in larger sizes by using liquid rheostat. Speed is varied by means of control on secondary windings of motor. Horsepower range — 5 hp and up. Speed adjustment range — 30 to 96 percent of synchronous speed for fan duty.

CHALMERS

PRODUCTION COST

Cut 2/3

You Can Make a Similar Saving in Your Assembly Department!

DPS POWER SCREWDRIVERS assembling automobile arm rests

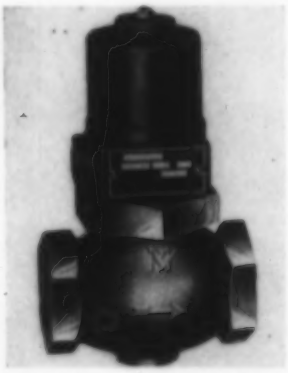
● These two machines maintain a production rate in excess of that previously attained by six hand operations, effecting an immediate saving of 66⅔%. This versatile equipment, used in prominent plants everywhere, can be adapted to your individual needs—So, get more action in your Assembly Department now—more speed—more profit. Write us, give details and our trained engineers will work out the proper solution of your problem.

DETROIT POWER SCREWDRIVER CO.

2801-A W. FORT ST. DETROIT 16, MICH.

New Parts

(Continued from Page 275)



less valve has a globe bronze body with screwed ends in sizes of 1 to 3 in. Pilot connections can be specified. Valve can be made to order with a handlift to provide an emergency or by-pass control. Made by **Magnatrol Valve Corp.**, 71 Fifth Ave., Hawthorne, N. J.

Circle No. 116, Page 217, for more data

Magnetic Counter 117

speed is 700 counts per minute

This small reset magnetic counter is suitable for moderate counting duty where extremely long life is not required. Actuation may be by any type of switch, relay or

photoelectric unit. Maximum recommended speed is 700 counts per minute. Units are available for 24 and 110-v ac-dc operation. Standard counters have three figures, but models with four figures can be ordered. Made by **Veeder-Root Inc.**, 28 Sargeant St., Hartford 2, Conn.

Circle No. 117, Page 217, for more data

Capacitors 118

operate at 125 C

Hermetically sealed in ceramic cases, these Pacer capacitors operate at temperatures up to 125 C. Use of a ceramic shell minimizes

How a shift in gears saved $256,000

Five million MUELLER BRASS CO. forged ring gears improve automatic transmission operation . . . at lower cost to the manufacturer.

Ever since one of the leading manufacturers of automotive transmissions began using ring gears forged from Mueller Brass Co. bearing bronze, production costs have been cut nearly $256,000. That's because the rough forging weighs less and is closer to finished size than a sand cast ring gear formerly used. This shift in gears resulted in a savings in metal costs, greatly reduced machining time and increased tool life. In addition, the use of forged gears has cut scrap loss and eliminated costly inspection rejects.

The performance of these forged ring gears is also far superior to the sand cast gear, which had a tendency to flake away and crack around the teeth, causing failures. More than five million forged ring gears have now been used in these transmissions without a single failure. Being porous, the sand casting was difficult to balance, but the forging has a dense, homogeneous structure that helps keep it in perfect balance.

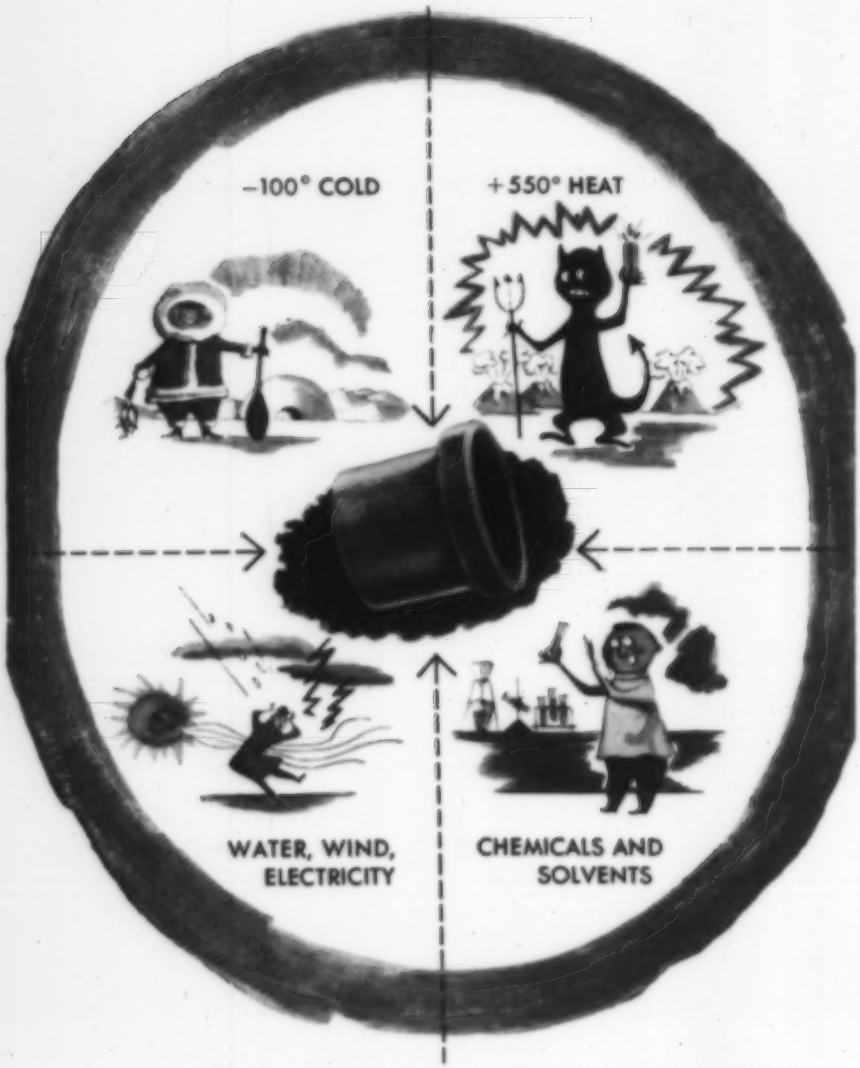
Strong, long-wearing non-ferrous metal parts, forged to your specifications by Mueller Brass Co., can help reduce your costs and improve the performance of your products just as they have done in this transmission application. For complete information, write us today.

Write today for your complete set of Mueller Brass Co. engineering manuals.

MUELLER BRASS CO. PORT HURON 15, MICHIGAN

134

A typical day for a rubber part molded from SILICONE by ROTH



Do you have a rubber part problem that can't be solved due to temperature extremes, weathering, resistance to chemicals or poor dialectric properties? If so, ROTH Rubber may have the answer in molded *Silicone* parts. It costs only a phone call or letter to find out if ROTH can solve your problem. Why not let ROTH work on it for you? No obligation.

Engineers and Rubber Buyers!

Write for your free Roth Rubber Sampler. This unusual kit contains actual rubber samples with hardness from 5 to 100 Durometer...gives ASTM specs and lists uses for each sample. Sorry, but offer must be limited to engineers and rubber buyers only. Please ask for Roth Rubber Sampler No. **MD9.**

ROTH RUBBER COMPANY

1856 S. 54th Avenue, Chicago 50

Custom Manufacturers of Industrial Rubber Products Since 1923

New Parts

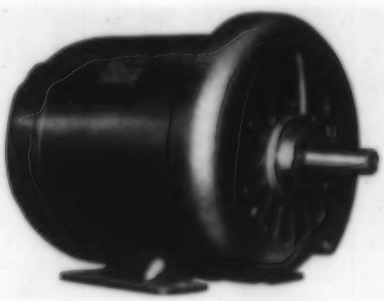
capacitance between the capacitor section and ground. Glass-to-metal solder seals provide excellent resistance to the effects of humidity and temperature, as well as stability under all operating conditions. Impregnation with an inert synthetic impregnant eliminates necessity of voltage derating for continuous operation at temperatures up to 125 C. Made by **Sprague Electric Co.**, 167 Marshall St., North Adams, Mass.

Circle No. 118, Page 217, for more data

Fractional-Hp Motor 119

½-hp model is built to rerated frame specifications

Totally enclosed fan-cooled ½-hp motor can be used in dirty, dusty, fume and mist-laden atmospheres. It is built to NEMA rerated frame specifications and has a sturdy



aluminum rotor with skewed laminations. The ventilating fan, integrally cast with the rotor, acts as a rotating seal to provide efficient cooling when the motor is operated in either direction. Made by **Century Electric Co.**, 1806 Pine St., St. Louis, Mo.

Circle No. 119, Page 217, for more data

Manual Starters 120

for across-the-line starting

Single and double-pole types of toggle switch-operated ac manual starters operate on a maximum of 220 v, 25 to 60 cycles. Designed

Short cuts speed printed-circuit design at Brush Electronics Co.

"3-day job"...done in 3 hours

Brush Electronics Co., a Division of Clevite Corp., Cleveland, Ohio, finds countless uses for photographic materials and techniques in designing more than 700 products.

Take the draftsman working on that printed-circuit diagram, for example. The original practice was to draw such circuits in ink on heavy Bristol board.

Now, the job is done in a fraction of the time by positioning precut circles and lines, with adhesive backing, on a form. This is reproduced on Kodagraph Autopositive Film, a positive copy being obtained directly without a negative step. This reproduction—with dense black photographic lines on a translucent base—is sent to the vendor who makes the printed circuits.

Brush has also found that duplicate tracings, made quickly and economically on roomlight-handling Kodagraph Autopositive Paper or Film, are the key to further savings when drawings must be revised, or vendor prints reproduced. Such duplicates are continually being used in place of originals for reference and print making . . . are protection against possible loss or unavailability of the originals.

And Brush further streamlines drafting and engineering activities with the help of other Kodak materials—uses Kodagraph Contact Fine-Line Paper for revising and combining drawings, and making high-quality offset plates . . . uses Kodalith Film in preparing "pictorial" assembly drawings, reduced-size drawings, handbook pages, graphs. *Sometimes four or five materials are used on one job, for top-quality results and savings at every step.*

To learn the ways Kodagraph and other Kodak reproduction materials can serve you, just mail coupon below, or get in touch with your local blueprinter.

Kodagraph Reproduction Materials

New booklet is jam-packed with valuable tips on saving drafting time, protecting drawings, getting better prints.

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Graphic Reproduction Division, Rochester 4, N. Y.
Gentlemen: Please send me a free copy of your new booklet on Kodagraph Reproduction Materials.

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Norgren Spray-Lube System as applied by Square D Co.

to multiple tapping operation, speeds production 30%

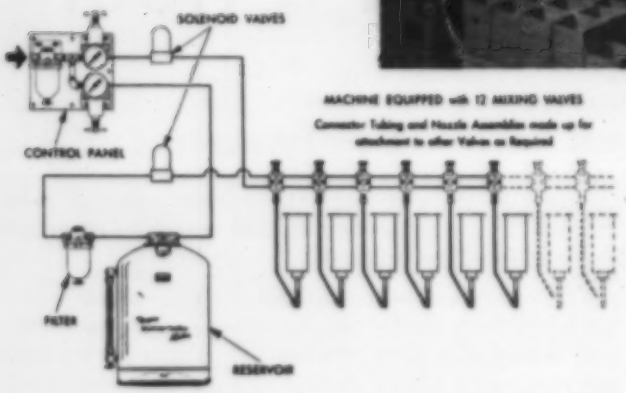
and in addition:

eliminates time and labor formerly required for draining and wiping tapped parts

relieves one man for more productive work

elimination of flood system greatly improves working conditions

substantial saving in lubricant


SOLENOID VALVES
CONTROL PANEL
MACHINE EQUIPPED with 12 MIXING VALVES
Connector Tubing and Nozzle Assemblies made up for attachment to other Valves as Required
FILTER
RESERVOIR

This tapping machine in the Square D Company production line handles a wide variety of tapping operations requiring as many as 12 taps in simultaneous operation. On job shown, tapping 3 holes in each of 2 switchbox covers, Norgren Spray-Lube System increased production 30% . . . eliminated the cleaning process. Even greater increases were reported on other jobs.

The unpleasant and hazardous disadvantages of the previous flood system, splashing lubricant over the operator and the surrounding floor, has been eliminated by Spray-Lube. Lubricant saving (Stanicut No. 107) has been substantial. Solenoid valves permit the Spray-Lube System to be actuated only when taps are approaching and contacting the work.

Norgren C.A. CO
3442 So. Elati, Englewood, Colo.

For complete data on this Norgren Spray-Lube application write for Blueprint SL 5 or phone the Norgren representative listed in your telephone directory classified section under Norgren Pneumatic Products.

New Parts

for manual across-the-line starting of small single-phase ac motors, they have adequate wiring space and trip-free silver-to-silver contacts. Bimetallic thermal overload protection is provided with interchangeable heaters covering the entire starter range. General purpose, weatherproof and explosionproof enclosures and open or flush types with single gang flush plate are offered. Made by **Clark Controller Co.**, 1146 E. 152nd St., Cleveland 10, O.

Circle No. 120, Page 217, for more data

Overheat Protector 121

mounts in motor windings

Intended for shaded-pole and permanent split-capacitor fan motors, miniature tubular-shaped type B9500 overheat protecter can be mounted directly in motor windings or small transformer enclosures. Spencer disk-type thermal element assures positive snap-

action make and break. Snap element and contacts are enclosed in molded phenolic case. Sealed unit withstands varnish dipping and baking. It is rated 300 v, maximum; 10 amp, maximum, at 115 v ac. Made by **Metals & Controls Corp.**, Spencer Thermostat Div., Forest St., Attleboro, Mass.

Circle No. 121, Page 217, for more data

Timer-Programmer 122

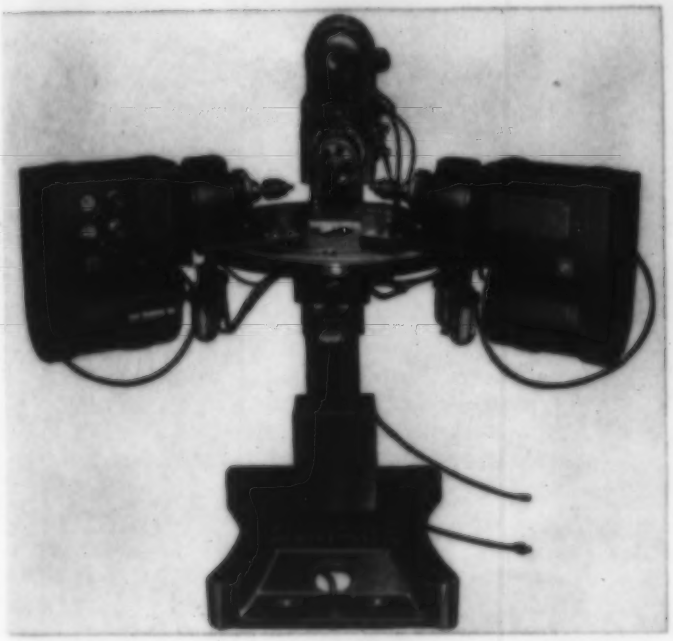
operates at any of ten speeds

Operating speed of the cam or program disk of the MG-1 timer

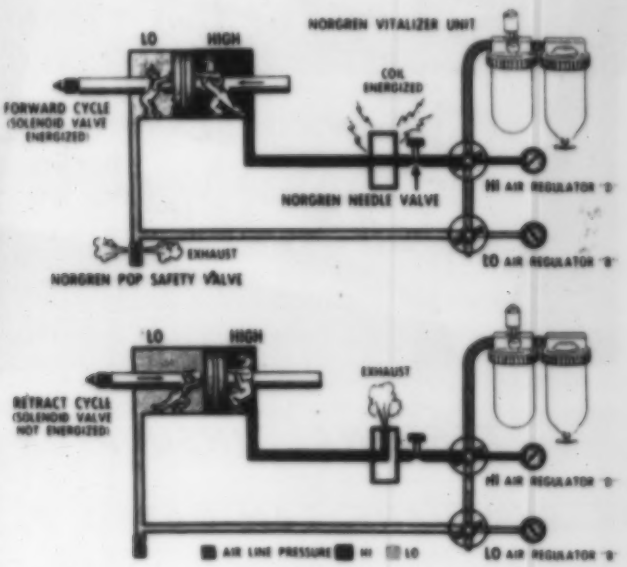
Norgren SOLVES DESIGN PROBLEM for DUMORE with MICRO-FOG lubrication

The recent development of the Dumore Series 24 Automatic Drill presented a difficult lubrication problem: *How to lubricate several small air cylinders requiring air at considerably less than 1 cfm.*

Only Norgren offered a solution—a special Micro-Fog Lubricator that would provide thorough lubrication at this extremely low air flow. Details of the Norgren Micro-Fog System are shown in the drawing below.



A Dumore Radial Drilling Application with three Series 24 Drill Units each equipped with a Norgren Micro-Fog Vitalizer Unit (Filter-Lubricator), a Norgren Pop Safety Valve and a Norgren Needle Valve



Schematic Drawing showing air lines from Norgren Vitalizer Unit to Air Cylinder

You, too, can take advantage of this specialized and extensive experience in Aerosol Lubrication

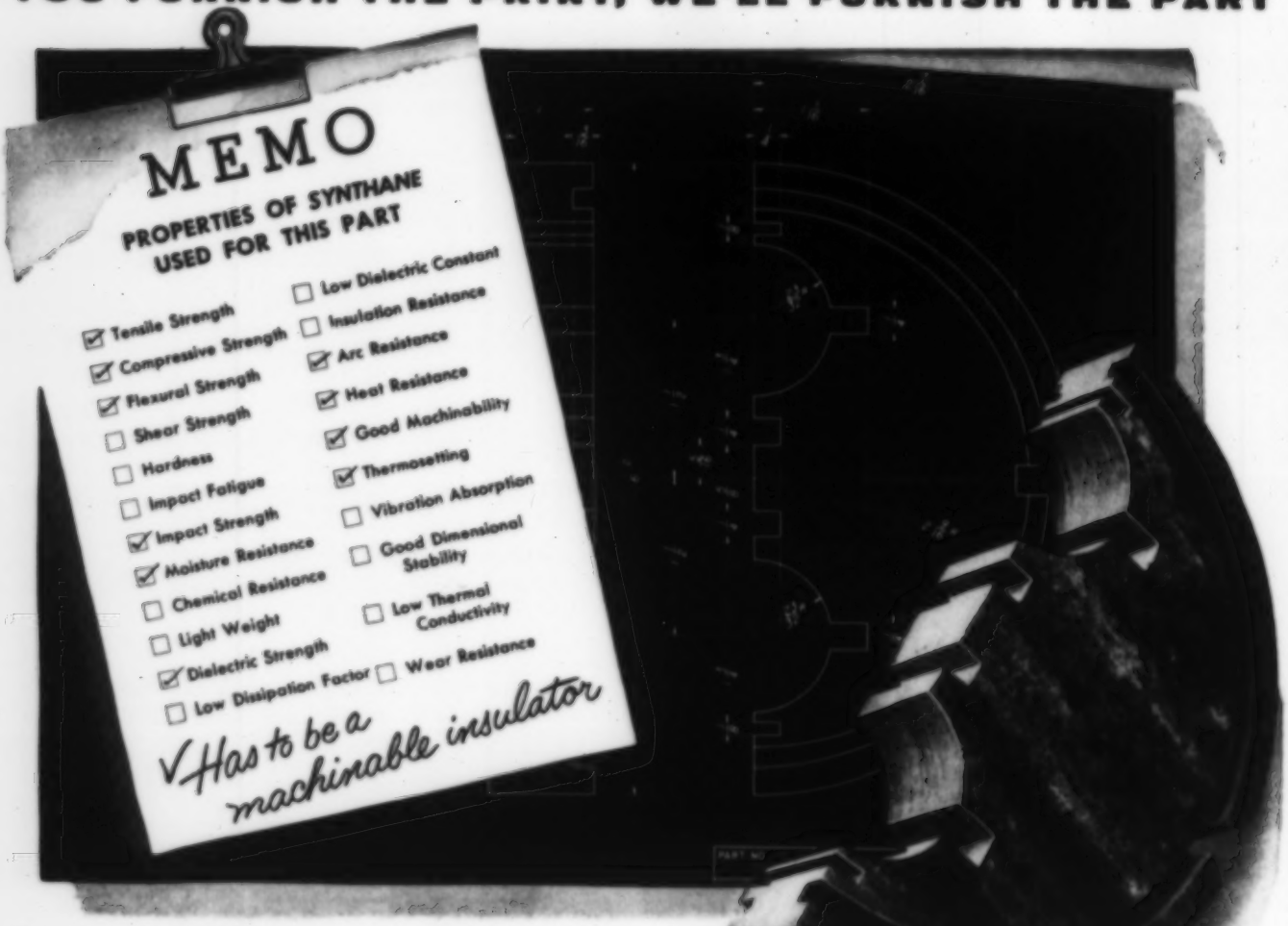
...JUST CALL NORGREN

THE PIONEER AND LEADER IN OIL-FOG LUBRICATION FOR 27 YEARS

For complete details on this Norgren Micro-Fog application, write for Norgren Blueprint No. 121, or phone the Norgren representative listed in your telephone directory classified section under Norgren Pneumatic Products.

C. A. Norgren CO.
3442 So. Elati, Englewood, Colo.

YOU FURNISH THE PRINT, WE'LL FURNISH THE PART



TERMINAL INSULATOR OF SYNTHANE LAMINATED PLASTICS RESISTS MOISTURE, HEAT, ARCING, BREAKAGE

Practically everything made requires a combination of several properties. And this terminal insulator is a shining example. It has to have high dielectric strength in a machinable insulator, good moisture resistance, excellent arc resistance, good heat resistance and mechanical strength. These and other requirements indicate *Synthane* laminated plastics for the job.

Starting with the blueprint, *Synthane* Corporation produces the needed base material with the right combination of properties, machines it with accuracy, and supplies the finished parts, with no waste, to the customer.

Each year *Synthane* turns out thousands of different finished parts. They are made from the more than 33 different grades of *Synthane* laminated plastics which are also regularly supplied to industry in sheets, rods, tubes, and molded parts. Good service and quality are characteristic of *Synthane* fabrication.

If you are looking for parts with many different properties — physical — mechanical — electrical — and chemical, in combination, *Synthane* may be your answer. Mail the coupon for information.

SYNTHANE CORPORATION, 5 River Road, Oaks, Pa

Please send me more information about Synthane laminated plastics and fabrication service.

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Title _____

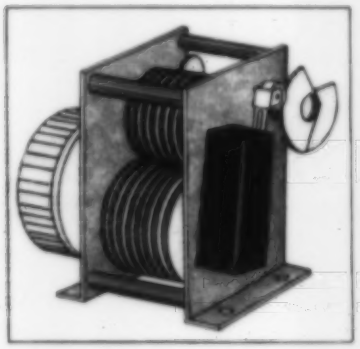
Company _____

Address _____

City _____ Zone _____ State _____

SYNTHANE
LAMINATED S PLASTICS

SYNTHANE CORPORATION • OAKS, PENNSYLVANIA



can be 1 revolution per 1, 5 or 15 minutes; 1, 4 or 12 hours; 1 or 2⅓ days, and 1 or 4 weeks. Speed changes are made instantly by moving the pickup gear along its shaft. Device can be furnished with cam as shown or with a program disk up to 6 in. in diameter. Also available is an optional adapter plate to hold four switches. The 6-in. disk will handle ten switches. Synchronous motor and all gears and shafts have Oilite bearings. Made by **Gorrell & Gorrell,** Haworth, N. J.

Circle No. 122, Page 217, for more data

Heavy-Duty Engine 123

rated at 3.2 to 6.8 hp

This four-cycle, single-cylinder air-cooled engine, designated model BKN, is rated from 3.2 to 6.8 hp in a speed range of 1600 to 3600 rpm. The engine is designed to

provide high power output per cubic inch of piston displacement. Its 2⅞-in. bore and 2¾-in. stroke provide a displacement of 17.8 cu in. It can be furnished with various gear reductions, clutch assembly, electric starter and generator or starter only. The standard model is built to operate on

(*Continued on Page* 288)

Means continuous production with no tear, less wear

on *Cambridge*

WOVEN WIRE CONVEYOR BELTS

No seams to tear! No lacers to wear! No fasteners to cut the belt! There are no weak spots in Cambridge belts because the ends are joined the same way the belt is made . . . you're assured of smooth, trouble-free operation.

Whether you're designing machines for your own operation or for resale, you can eliminate batch handling, cut costs, provide continuous production at controlled rates of speed with moving woven wire belts.

All-metal Cambridge Woven Wire Conveyor Belts are corrosion resistant and impervious to damage from constant operation at temperatures from sub-zero to 2100°F. Open mesh construction lets process atmospheres circulate freely for uniform cooling, heating, drying . . . provides flash drainage of solutions, rapid washing, quenching, cleaning, draining.

No matter how you look at it, CAMBRIDGE Woven Wire Conveyor Belts are invaluable aids to AUTOMATION . . . help beat your biggest competition, COST. They are made in any size, mesh or weave, from any metal or alloy. Special raised edges or cross-mounted flights are available to hold your product during movement.

Call in your Cambridge Field Engineer to discuss how you can cut ultimate costs by continuous operation. You can rely on his advice. Write direct or look under "Belting, Mechanical" in your classified telephone book.

BAGGED CEMENT . . . Smooth belt won't tear package. Spillage sifts through open mesh to be salvaged.

ASK FOR FREE 130-PAGE REFERENCE MANUAL illustrating and describing woven wire conveyor belts. Gives mesh specifications, design information and metallurgical data.

The Cambridge Wire Cloth Co.

WIRE CLOTH | METAL CONVEYOR BELTS | SPECIAL METAL FABRICATIONS

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Cambridge 11,
Maryland

OFFICES IN PRINCIPAL INDUSTRIAL CITIES

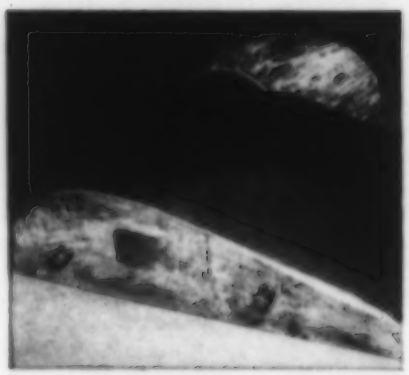
How much money can

Injection molding dies of Epon resin (left) reduce costs 80% for Adams Plastic Products, Cincinnati, Ohio. Duplicate patterns (center) are made to close tolerances with Epon resin by Crane Company, Chicago, Ill. Epon resin dies for outboard motor housing (right) are one-third cost of comparable metal dies for Clinton Machine Company, Maquoketa, Ia. Formulations for these three applications supplied by Kish Industries, Inc., Lansing, Mich.

Epon resin gives you these advantages for making tools and dies . . .

- Cast and cured at room temperature . . . no special equipment needed
- Cast to close tolerances . . . less machining and handwork
- Easily duplicated and altered . . . short production time

Epon resins are the epoxy polymers made exclusively by Shell Chemical Corporation.



Epon resin stretch dies developed and used by Lockheed Aircraft Corporation, Burbank, California, show high dimensional stability and strength.

Toy models of Epon resin made by Ber-Design Associates, Irvington, N. J., stand up in duplicating machine during hob-making process at Columbia Engineering Company, Newark, N. J.

you save using

EPON® RESIN

to make TOOLS and DIES?

New resin can reduce tool production costs by 80%

PLASTIC TOOLING now has graduated from the short-run experimental stage to the profitable production stage . . . thanks to the unusual physical properties of Epon resin.

Saves time and labor

Little machining and handwork are required to finish Epon resin tools, dies, and patterns, because the material can be cast to very close tolerances. No specialized equipment is needed, because Epon resin tools are cured at room temperature.

Tools resist wear

Other advantages of Epon resin tools are that they withstand great pressures, are unaffected by chemicals and a wide range of temperatures, and maintain a high resistance to abrasion and corrosion.

Where Epon resin tools are used

Draw dies, drop-hammer dies, and injection molding dies for polystyrene . . . are some of the Epon resin tools now serving a variety of industries. Drilling, welding, routing and checking fixtures, foundry patterns, and vacuum-molding dies . . . all made of Epon resin, are also in daily production.

Find out more

Savings of 80% over the cost of comparable metal tools have been reported by tool- and die-makers. How much can you save in your operations? Best way to find out—write for technical literature on the use of Epon resin in tool and die applications.

SHELL CHEMICAL CORPORATION

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TUTHILL SIMPLIFIES PUMP SELECTION

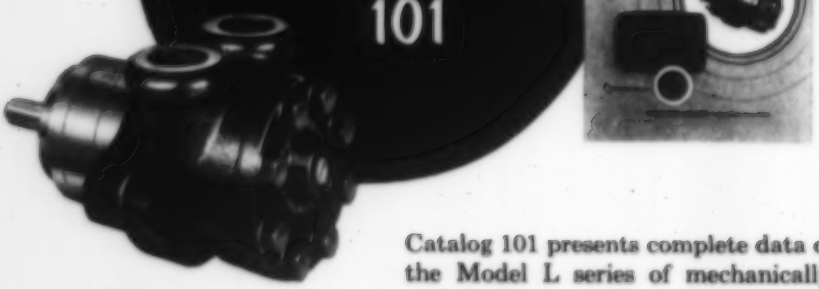
New Cataloging Plan Provides Practical Short-Cuts to Pump Specifications — Helps You Pick The Right Pump for the Purpose

If Your Specifications Call for Pumps for...

- LUBRICATION
- HYDRAULIC SERVICE
- TRANSFER
- CIRCULATING
- BURNING OILS

In capacities from 1/3 to 6 g.p.m. and pressures up to 600 p.s.i.

...Write for Tuthill Catalog 101



Catalog 101 presents complete data on the Model L series of mechanically-sealed, rotary, internal-gear positive displacement pumps.

TUTHILL PUMP COMPANY

Dependable Rotary Pumps since 1927

939 East 95th Street, Chicago 19, Illinois

Canadian Affiliate: Ingersoll Machine & Tool Co., Ltd. • Ingersoll, Ontario, Canada

New Parts

(*Continued from Page 285*)

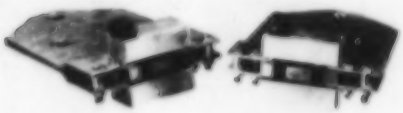
gasoline, but engines can be equipped to operate on kerosene, butane, propane or natural gas. Made by **Wisconsin Motor Corp.**, 1910 S. 53rd St., Milwaukee 14, Wis.

Circle No. 123, Page 217, for more data

Deflection Indicator 124

detects excess vibration

Magnetic amplifier type deflection indicator utilizes a visual or audible alarm system to call attention to excess deflection or motion of operating equipment. It operates basically on a balanced bridge principle. In typical application to rotating machinery, two external pickup coils of matched impedances (illustrated) are bracket-mounted on opposite sides of the shaft, with equal air gaps between each coil



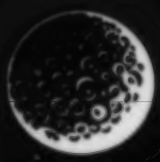
and the shaft. Connected in series, these coils form half of the circuit, and a 60-cycle, 110-v power source forms the second half. A lead from the midpoint of the coils is connected through a rectifier to the midpoint of the power source. Deflection or vibration sufficient to vary the air gap beyond preset limits allows a current to flow in the circuit, initiating action which will set off the warning indicator or shut down the machine. Made by **Allis-Chalmers Mfg. Co.**, Milwaukee 1, Wis.

Circle No. 124, Page 217, for more data

Aluminum Foil Nameplates 125

are laminated to bonding material

Speedy-Cals are composed of 0.003-in. thick Reynolds aluminum foil laminated to a layer of bonding material. The nameplates can be made in almost any shape and size, and the anodized surface of the aluminum foil can be printed in most standard colors. Application procedure consists of cleaning the work surface with carbon tetrachloride, immersing the nameplate in clear water at room temperature



336,099 miles of extrusions!

Our extruders have turned out enough plastic and rubber extrusions to reach to the moon and halfway back. In compiling this vast experience General Tire's Industrial Products Division has supplied thousands of original equipment manufacturers with just about every known type of extrusion. No job is too large, too small or too complicated for our design and production staff. Perhaps *you* can benefit from the fantastic extrusion mileage we've accumulated down through the years.

For literature or further information write to The General Tire & Rubber Company, Wabash, Indiana, Department E2.

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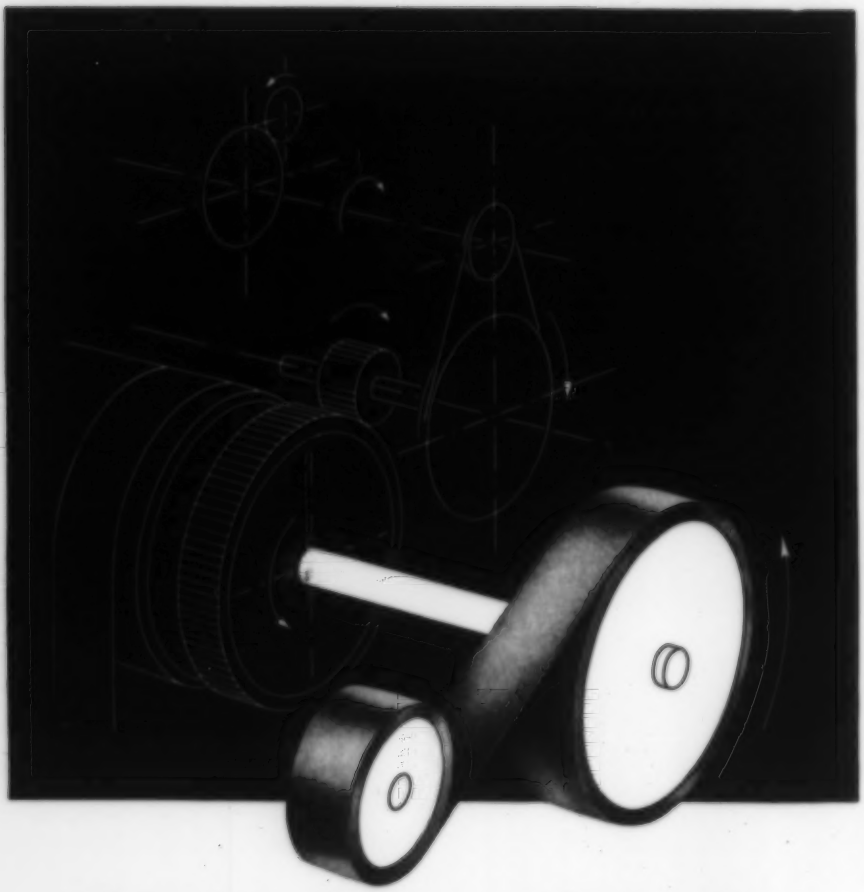
WABASH INDIANA

"From Plans to Products in Plastics and Rubber"



DRIVE IT WITH A NEG'ATOR®
constant-force spring

Ideal for use as a powerful, constant-torque motor is the NEG'ATOR Spring, the revolutionary constant-force spring component which is giving design engineers new ideas.

They're using the NEG'ATOR Spring as a motor in two ways. A light torque motor is made by winding the NEG'ATOR Spring around two drums of unequal size. The tendency of the material to recurl to its *preset curvature* around the smaller drum imparts a constant output torque to the shaft of the larger (output) drum. A more powerful and efficient motor is made as shown above—by *reverse*-bending the free end around the output drum.

Think of how products can be improved, problems solved with a long-running, constant-torque motor. An aircraft designer with a critical counterbalance problem found out. So did a manufacturer of self-retrieving, 50-foot, steel tapes . . . a motion picture camera maker . . . an engineer who developed a new precision mechanical computor . . . many others with drive unit, long deflection, and counterbalancing design problems.

And, so will you when you get the full story. Ask us for a copy of Bulletin 310N, "The Story of the NEG'ATOR Spring." We'll send it immediately without cost.

HUNTER SPRING COMPANY
3 Spring Street, Lansdale, Pennsylvania
(*near Philadelphia*)
SPRINGS • STAMPINGS • TEST APPARATUS

New Parts

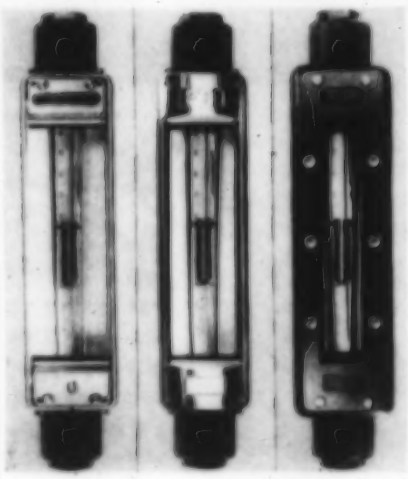
for about a minute, then drying it between sheets of blotting paper, removing a cellophane protective film from the back, placing the nameplate in position and fixing it with a small roller. Maximum bonding strength is reached in 24 hours, or in a shorter time if necessary by using a heating iron. The nameplates will stick to smooth surfaces such as porcelain, glass, plastic or metal, or to any painted surface. They are easily attached to convex or concave areas. Made by **North Shore Nameplate Inc.**, 214-27 Northern Blvd., Bayside, N. Y.

Circle No. 125, Page 217, for more data

Flowmeters 126

improved to provide greater visibility

Visibility of the metering tube has been improved 100 per cent in 1700 series Flowrator meters. These variable-area flowmeters retain the float, metering tube and universal end fittings of the previous 700 series and have the same

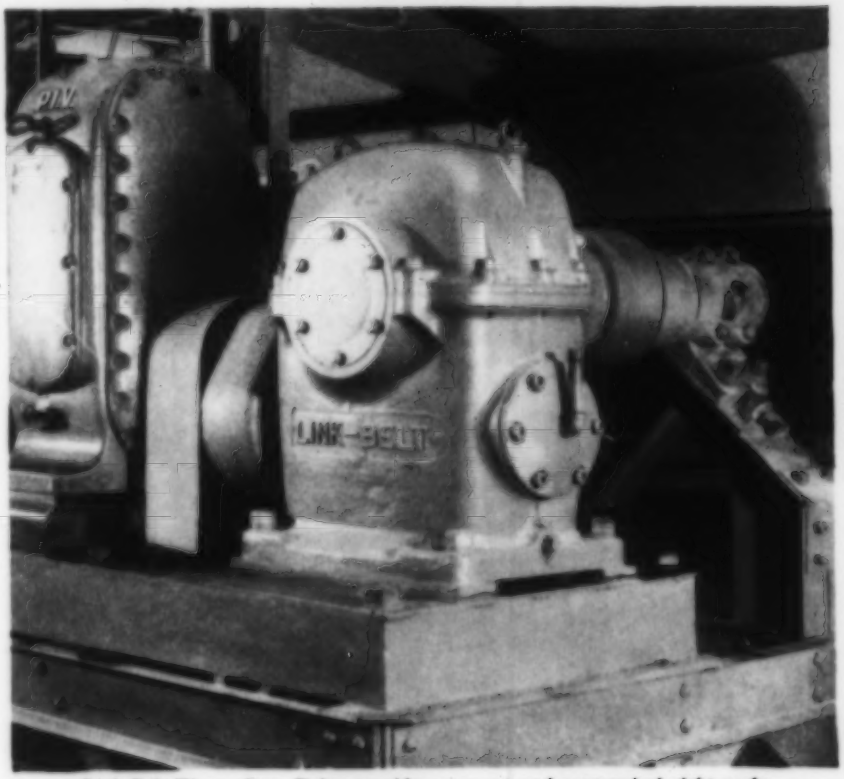


overall dimensions. Improved design uses one basic frame which, by changing covers, can be made into an enclosed or pressure-sealed meter. Built-in panel-mounting fittings permit mounting without special fixtures. An improved packing assembly is available in either Neoprene or in a hat type Teflon glass-to-metal seal with Neoprene compression rings. Made by **Fischer & Porter Co.**, Hatboro 35, Pa.

Circle No. 126, Page 217, for more data

Here's real versatility! LINK-BELT offers you

19 VARIATIONS in WORM GEAR DRIVES



Link-Belt Worm Gear Drive provides compact and economical right-angle power transmission to apron conveyor. Conveyor speed is readily changed by P.I.V. Variable Speed Drive to suit operating conditions.

Meet specific needs from industry's most comprehensive line

WHATEVER the need . . . whatever the speed — Link-Belt Worm Gear Drives can meet your requirements for simple, compact, fixed-ratio speed reduction. With them, you can change the direction and velocity of power . . . match high motor speeds to modern production needs with the least power loss, best possible balance of torque and horsepower ratings.

Choose from a wide selection for fractional or large horsepower requirements. Available with horizontal and vertical housings to permit convenient connections to prime movers and driven machinery.

Single-Worm Gear Drives in ratios from 3.1:1 to 100:1 with output capacities to 97.9 hp.

Helical-Worm Gear Drives in ratios from 26:1 to 540:1 — output capacities to 56.7 hp.

Double-Worm Gear Drives in ratios from 26:1 to 8000:1 — output capacities up to 26 hp and 124,000 inch-pounds torque.

8 of 19 types in the broad Link-Belt line

Type WB—Single reduction, worm below gear, horizontal output shaft.

Type HWB—Helical gear first reduction, worm gear final reduction. Worm below gear, horizontal output shaft.

Type DWB—Double worm reduction gear, horizontal output shaft.

Type WVS—Single reduction, worm on top of gear, horizontal shaft with screw conveyor flange.

Type WV—Single reduction, vertical output shaft (up or down).

Type HWV—Helical gear first reduction, worm gear final reduction. Vertical output shaft (up or down).

Type DWV—Double worm reduction gear, vertical output shaft (up or down).

Type WVT—Single or double reduction overhead conveyor drive.

For full information, consult your local Link-Belt office or authorized stock-carrying distributor. Or write today for Book 2324-A.

LINK-BELT

ENCLOSED DRIVES

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 13,940

OFTEN:

TWO HEADS ARE BETTER THAN ONE

Sometimes a double head is the only solution to your part or fastener problem. This steel spacer is an excellent example of a single double-headed part that has replaced a more expensive 3 piece part. Not only was the spacer itself much less expensive but actual assembly cost was cut almost 30%. HASSALL double-heading really paid off on this one.

Double-heading is only one example of the almost limitless possibilities Hassall cold-heading offers you. If you have a fastener problem just send us samples or specifications for a quotation.

WRITE FOR CATALOG . . . . . with it we will send you our popular decimal equivalent wall chart. John Hassall, Inc., Box 2197, Westbury, L. I., N. Y.

HASSALL

SINCE 1850

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NAILS, RIVETS, SCREWS AND OTHER COLD HEADED FASTENERS AND SPECIALTIES

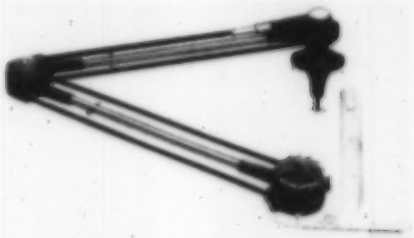
ENGINEERING DEPARTMENT

EQUIPMENT

Drafting Machine 127

brake arrangement operates with minimum adjustment

Functions of a T-square, 45, 60 and 30-deg triangles, precision mechanical protractor and scales are combined in this new Vemco drafting machine. Its coin-slotted brake arrangement does not require frequent adjustment. Adjusting of the screw is performed at the top of the elbow, where it is convenient to the user but not likely to be disturbed by accidental handling.



Large braking area of the machine is lined with long-wearing material. Standard machine has a protractor marked in 1-deg divisions and a double vernier reading to 5 min. Models are available with 24, 30 or 36-in. arms or special length arms. Design also incorporates automatic indexing, arms pivoted in brackets so that scales lie flat, central skid button to facilitate movement of scale arm, large drafting head handle and completely reversible elbow. Made by **V. & E. Mfg. Co.**, P. O. Box 950M, Pasadena 20, Calif.

Circle No. 127, Page 217, for more data

Printed Circuit Kit 128

aids in developing circuits

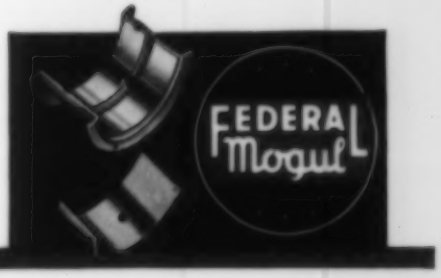
Printed circuit kit for experimental and development engineers contains an 8½ x 5-in. sheet of copper-clad laminate and all other materials required to make etched or printed circuits. Also included is a booklet of instructions and printed circuit design information. The

A Control Factor in Performance!

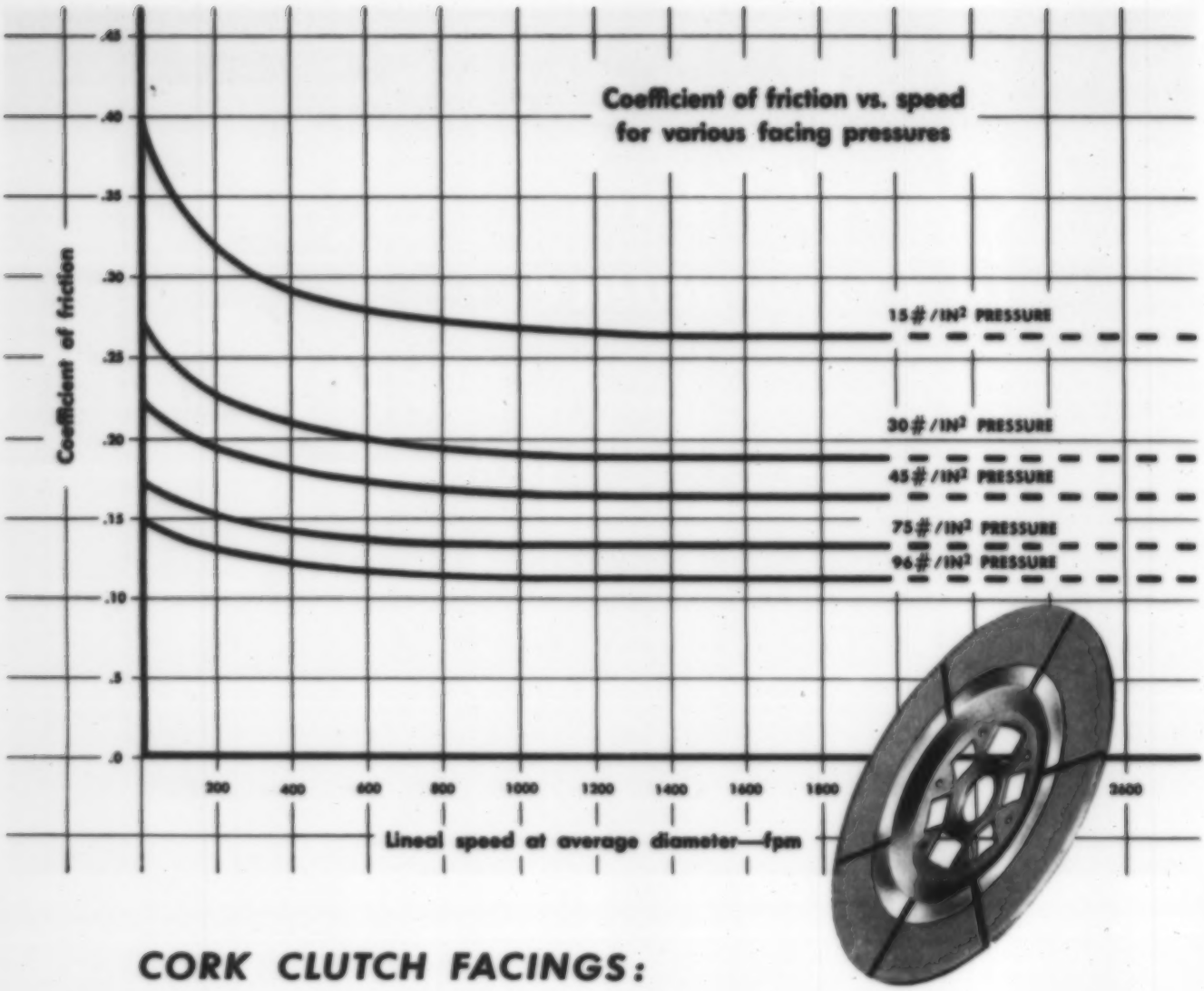
RESEARCH • DESIGN • METALLURGY • PRECISION MANUFACTURING

Here are industry's work horses . . . dependable diesel engines. They power trucks, tractors, construction equipment. As mobile units they bring light, power and compressed air to the job. As stationary units they light towns and villages. As stand-by units they provide emergency power and light. Their dependability is vital. To help assure this dependability we supply quality bearings for many sizes and types of diesels and are a major supplier to diesel engine builders. **FEDERAL-MOGUL DIVISION,** Federal-Mogul-Bower Bearings, Inc., Detroit 13, Michigan.

SINCE 1899



FEDERAL-MOGUL
DIVISION



CORK CLUTCH FACINGS:

High torque capacity at low engagement pressures

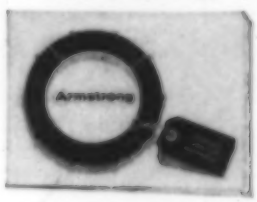
The curves above show how a typical cork-compounded clutch facing delivers high coefficients of friction under engagement pressures ranging from a low of 15 psi up to 96 psi.

The ability of cork to work efficiently at these low engagement pressures has helped many clutch manufacturers get high torque capacity at low cost—and eliminate wear and improve engagement. In automotive transmissions, for example, various cork plates are used under unit pressures of 20 psi to about 150 psi with excellent results.

Cork's versatility also enables designers to get just the engagement characteristics and torque capacity they need for specific applications. For example, the performance curves shown above can be varied—even reversed—by using unslotted plates, or by using waved plates. This flexibility gives designers wide freedom in clutch design which is of value whether their goal is cost reduction or performance improvement.

Perhaps the most surprising thing about cork is how long it lasts. As a matter of fact, Armstrong-compounded facings in the automatic transmissions of 13 American makes of automobiles normally outlast the cars themselves.

If you'd like to know more about cork facings, get in touch with Armstrong today. Write for your copy of our new 16-page illustrated booklet, "Resilient Friction Materials." Armstrong Cork Company, Industrial Division, 7211 Dean Street, Lancaster, Pennsylvania.



Armstrong FRICTION MATERIALS

. . . used wherever performance counts

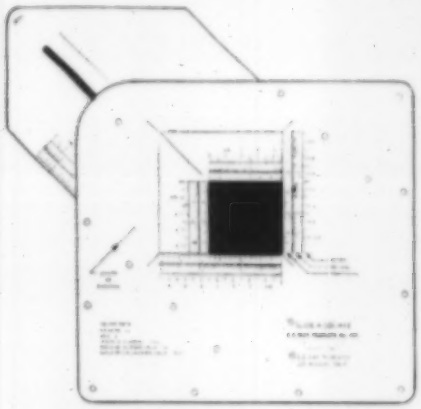
kit can be used to make two average size miniature circuits or one standard size circuit. Available from **Control Circuits Inc.**, 24 Broad St., Middletown, Conn.

Circle No. 128, Page 217, for more data

Square Template 129

also calculates length of diagonals

Slide-A-Square template is adjustable for drawing squares having up to 3-in. sides. Length of the diagonal of any square is automatically computed and indicated by



a pointer. Three scales are provided, with 1/32-in., 0.02-in. and 1-mm graduations. The template is of 0.020-in. rigid vinyl plastic. Made by **E-Z-Way Templates**, 1321 Nineteenth St., Santa Monica, Calif.

Circle No. 129, Page 217, for more data

Tape Potentiometer 130

has 144-in. slide wire

The Ta'Pot precision potentiometer is an accurate, manually operated, direct-reading device. It is a 144-in. straight slide-wire type with direct calibration for use in precision bridges and electronic equipment. The potentiometer consists of a vulcanized fiber tape with a resistance element bonded to the edge. It is calibrated in linear or nonlinear terms as required. Typical calibrations available are temperature curves corresponding to different type thermocouples, strain gage calibrations, resistance bulb calibrations, or direct readings in resistance values. It is accurate to within ±0.1-per cent.

(*Continued on Page* 298)

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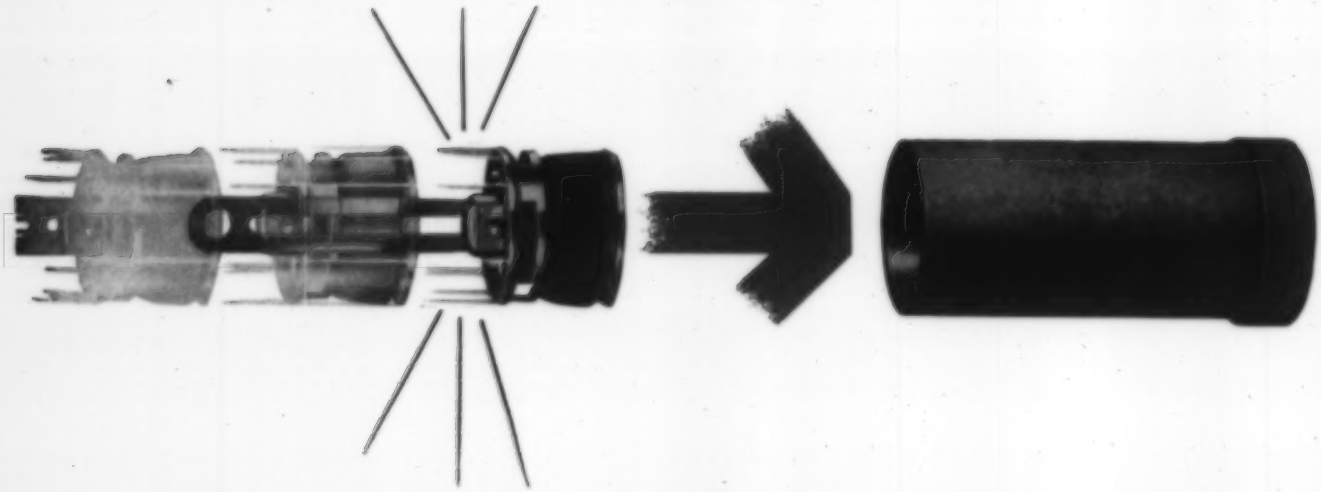

How to soak up shock and

Underwood Corporation did it by using Republic ELECTRUNITE Stainless Steel Tubing

This was the problem: find a material for the cylinder in the carriage shock absorber on an accounting machine. The cylinder must have an accurate bore, little variation in diameter, and negligible eccentricity. It must also have a suitable finish to reduce drag, because the piston which fits inside must be completely retracted in less than a tenth of a second.

Republic metallurgists suggested ELECTRUNITE Stainless Steel Tubing. It was drawn to meet dimensional requirements. The finish was excellent. And Underwood reports good service life because of excellent wearing qualities.

Republic Steel Corporation
3130 East 45th Street
Cleveland 27, Ohio

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- ☐ Republic Nuts and Bolts
- ☐ Republic Chateaugay Pig Iron

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Engineering Equipment

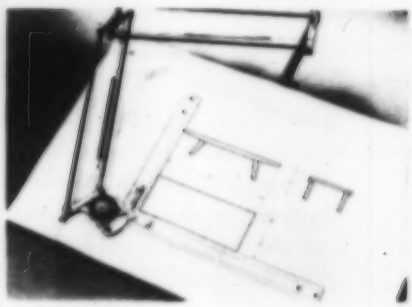
(*Continued from Page 295*)

Power dissipation is 2 w. Unit is available in resistances from 75 to 30,000 ohms. Size is 4⅞ x 3 x 2¼. Made by **Howell Instrument Co.**, 1106 Norwood, Fort Worth 7, Tex.

Circle No. 130, Page 217, for more data

Drafting Machine 131

for general drafting



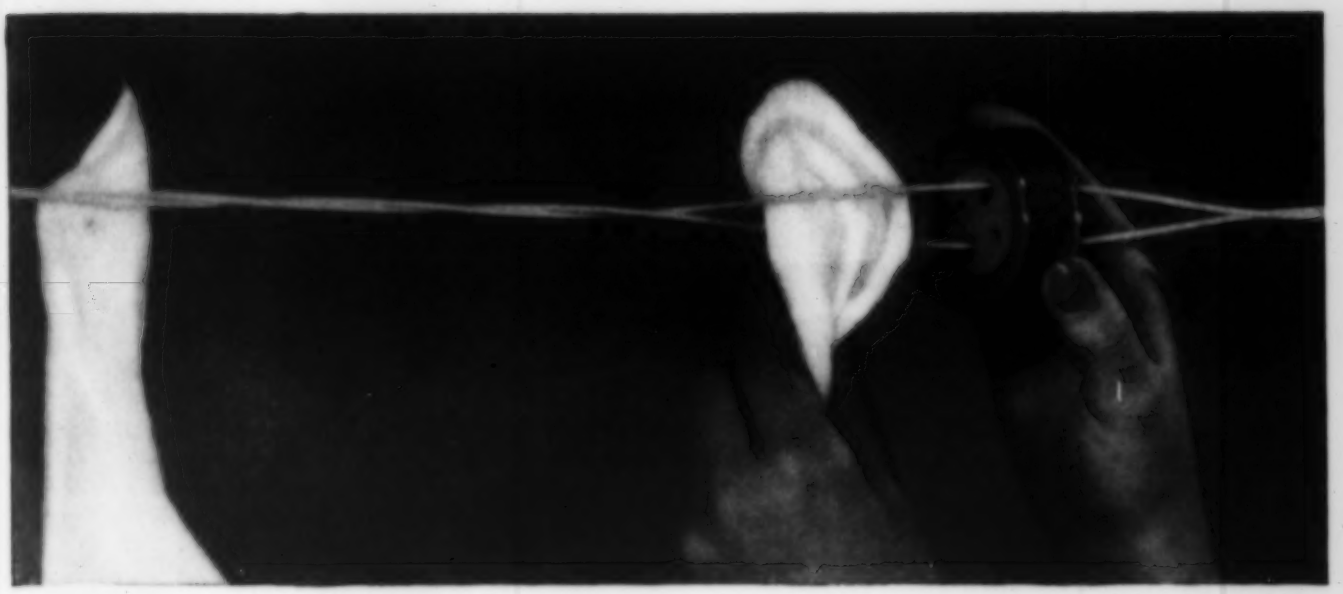
This Swedish-made drafting machine can be used for drawing plans or scale drawings, for general drafting or any graphic operation requiring a T-square and triangle. Instrument is constructed of cold-drawn steel tubing and machined steel and plastic parts. It sets and holds any angle and its complement. Protractor head reads from 90 through 0 to 45 degrees, with automatic quick-set lock every 15 degrees. Head also locks easily at any desired angle between the 15-deg stops. Available from **Walpole Co.**, 419 Boylston St., Boston 16, Mass.

Circle No. 131, Page 217, for more data

Portable Oscillographs 132

for four or six-channel recording

Two portable oscillographs, weighing 36 and 48 lb, provide full range instrumentation. Each unit offers 16 chart speeds with travel from



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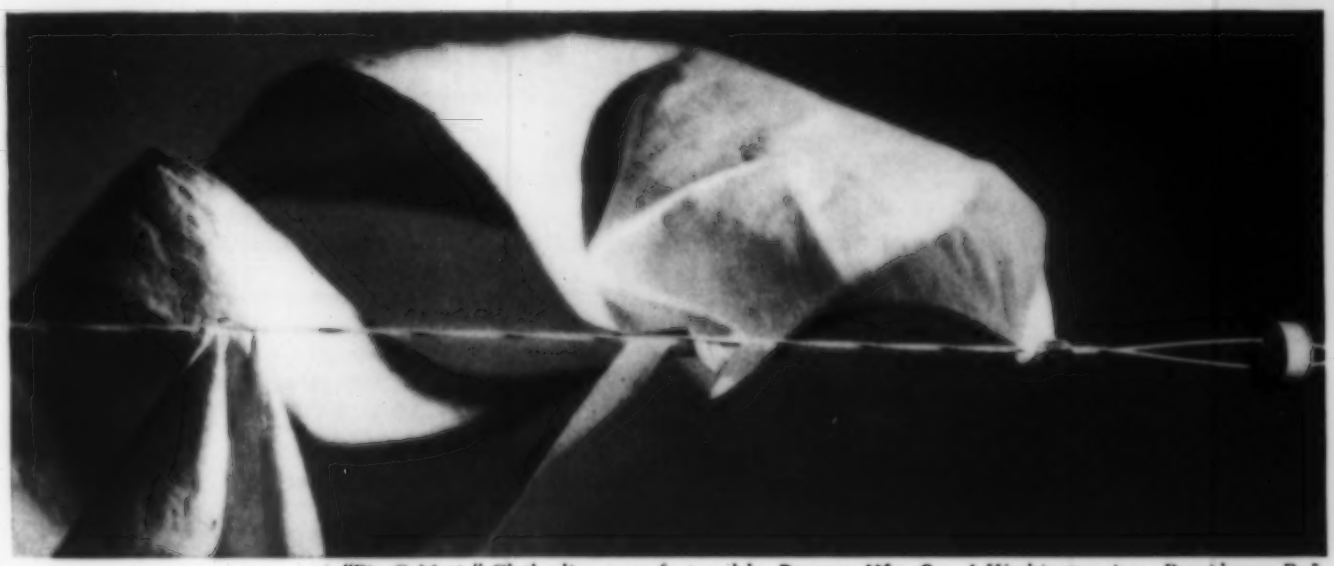

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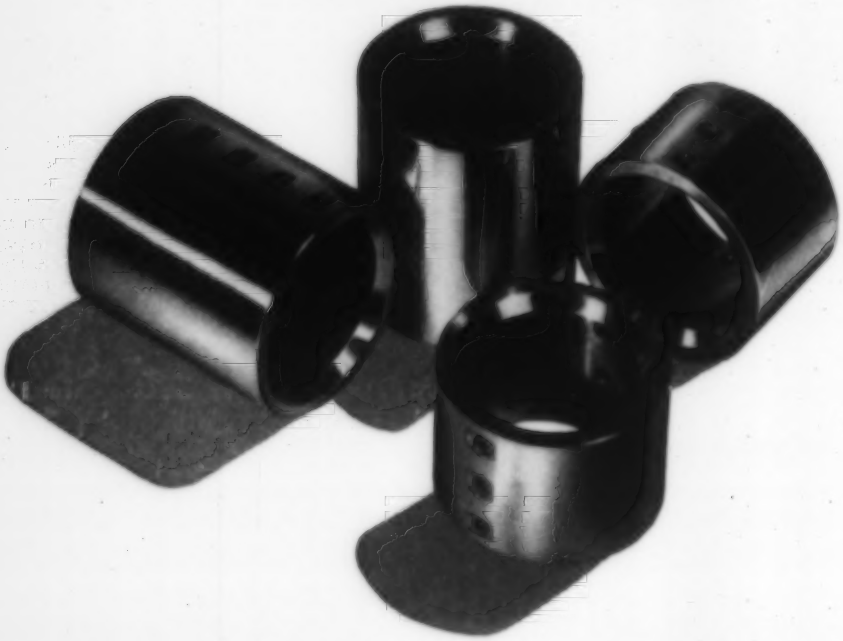

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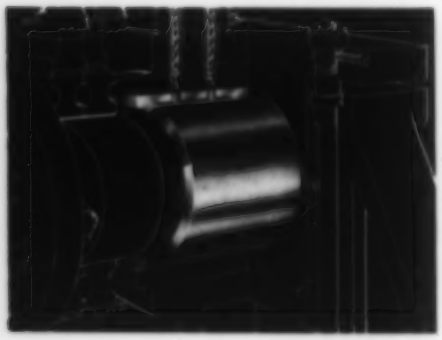

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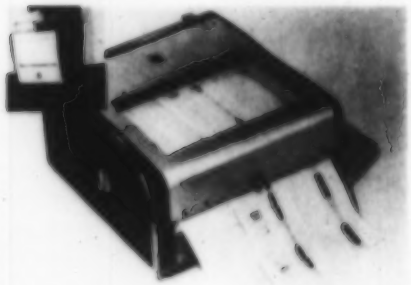

and can record a wide range of signals with optimum resolution. A control selector permits either local or remote control. Easy access to the writing table is provided. Made by **Brush Electronics Co.**, 3405 Perkins Ave., Cleveland 14, O.

Circle No. 132, Page 217, for more data

Hand Tachometer 133

in seven speed ranges from 50 to 10,000 rpm

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direction of rotation without adjustment. Instrument is unaffected by temperature, moisture, electrical currents or magnetic conditions. A stop button makes possible the retention of dial readings. Made by **Jones Motorola Corp.**, 432 Fairfield Ave., Stamford, Conn.

Circle No. 133, Page 217, for more data

How to Control Temperature With Liquid Filled Bellows Systems

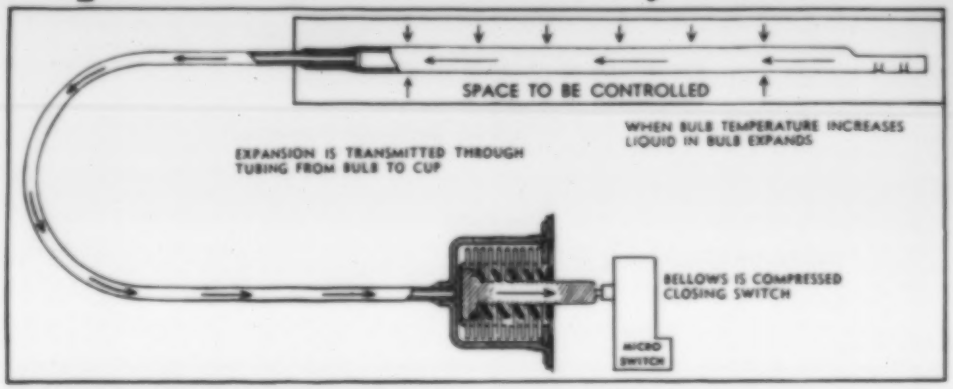


Fig. 1. Liquid filled bellows systems provide remote control of a wide temperature range with a single actuating device. Bellows actuating movement is closely proportioned to the temperature range throughout the entire operating range of the system. The differential required to operate these devices is directly related to the range of temperature to be controlled. A device that provides control over a wide temperature range normally requires a relatively wide differential to operate it at any given setting. However, proper design of switches or valves can make these systems quite sensitive.

ADVANTAGES OF LIQUID FILLED BELLOWS CONTROLS

For the remote control of temperature, liquid filled bellows assemblies provide simple, efficient, direct-acting systems. Utilizing the thermal expansion of a liquid selected for the particular application, the bellows responds with sufficient force and degree of motion to actuate switches and valves without the need for elaborate amplifying systems.

They can be used for temperatures as low as −100 F. and as high as 700 F. In addition, these units provide "one knob control" of temperature over a *wide range*. A common example is the ordinary domestic oven in which a selected temperature can be maintained anywhere in the range from 150 F. to the top limit of the oven — usually about 600 F.

Since these systems operate on the thermal expansion of a liquid, they are insensitive to ambient pressure changes.

Liquid filled bellows systems are highly versatile and offer many possibilities to designers seeking low cost, accurate, dependable temperature controls for consumer, industrial or commercial product applications.

Long experience record. Being one of the most widely used thermostatic controls, a great deal is known of the inherent characteristics of liquid filled thermostatic assemblies. Performance can be accurately predicted for applications when operating conditions are known. Furthermore, the design considerations are so well known that it is usually not difficult to design a liquid type thermostatic assembly to fit the requirements of any application for which this type of control is suited.

Operating principle. (fig. 1). In its simplest form, the liquid filled thermostatic assembly consists of a bulb, capillary and bellows. The bulb is the temperature-sensing element and is located in the chamber whose temperature is to be controlled. The bellows is the responsive element and can be located together with the switch or valve it will actuate at any remote location a reasonable distance from the bulb. A capillary, a special small bore tubing, connects bulb and bellows. The entire assembly — bulb, capillary and cup — is completely filled with a liquid chosen for the particular range of temperature to be controlled.

As the temperature in the chamber rises, the liquid in the bulb expands through the capillary into the cup, compressing the bellows and moving the attached rod to actuate a switch or valve.

DESIGN CONSIDERATIONS

Bellows stroke. The amount of bellows movement necessary to actuate the switch or valve varies with the nature of the application. Design of bulb volume and bellows effective area control the movement to meet these requirements. A large volume bulb and small bellows results in a long stroke and vice versa. Bellows of 15/32" or 9/16" diameter are common sizes.

The total stroke or travel to be expected of a bellows in this type of application is approximately 25% of its length.* This is the total amount of bellows movement available over the entire range of temperature which the device will encounter.

For example: a bellows one inch long will provide a total travel of about one-quarter inch.* Used in a temperature range of 500 F, total bellows movement would be 0.250" or 0.0005" per degree. In a 100 F range, movement per degree would be .0025".

In computing bellows movement care must be exercised to consider the highest ambient temperatures encountered during shipment, storage or extraordinary conditions of service. Heat applied to a fluid in a closed system can generate large forces and result in damage. A unit intended to control temperatures between 50 F and 70 F for example, may experience temperatures as high as 140 F. Bellows movement must therefore be figured for the range 50 to 70 F resulting from expansion of the liquid in the bulb (considering temperature of the bellows held constant at 70 F.) In addition, the entire volume of liquid in the bulb, bellows and capillary will expand between 70 and 140 F.

$$\therefore \Delta V_{tot} =$$

$$K[V_s \Delta T_c + (V_s + V_b + V_c)\,\Delta T_{amb}]$$
$$= K[V_s(70 - 50) + (V_s + V_b + V_c)(140 - 70)]$$

where

- K = Coefficient of expansion of fluid
- V_s = Volume of thermal sensing bulb
- V_b = Volume of bellows
- V_c = Volume of capillary
- ΔT_c = Control temperature range
- ΔT_{amb} = Ambient temperature range
- ΔV_{tot} = Total liquid expansion

This expansion divided by the effective area of the bellows will give the total movement over the complete range from 50 to 140 F. The total movement should not exceed the allowable travel discussed above. Temperature *lower* than the operating range need not be considered as a factor.

* For accurate information, refer to bellows table of characteristics obtainable upon request.

Fig. 4. Control of temperature for many industrial processes is achieved through liquid filled bellows assemblies. Typical applications: Elec. steam tables, bottles, ovens, furnaces.

Photo courtesy of United Electric Controls

Loading springs are generally used with liquid filled bellows systems. They make certain that the bellows follows the volume changes of the liquid accurately. Springs used for cup type assemblies are lighter than those required for equivalent open type assemblies (see fig. 2) because the natural spring of the bellows in a cup assembly actually helps the loading spring to perform its proper function. The open type bellows assembly opposes the loading spring and therefore, a heavier loading spring is required. Frictional forces for devices utilizing cup type assemblies are generally lower than those for equivalent open type units.

Bulb and filling medium. There are a number of liquids with properties suitable for use in thermostatic assemblies intended for service anywhere from −100F to 700 F. Some typical ones are shown in fig. 7. In addition to the consideration of adequate volume in relation to the bellows so as to provide sufficient actuating stroke, bulb design is concerned with securing the proper heat transfer so that temperature changes in the controlled chamber will be quickly reflected in bellows movement. Both filling medium and bulb design are critical elements and should be chosen only after consultation with Clifford engineers.

Responsiveness of liquid filled bellows assemblies is very good and they can be used in systems requiring rapid response. The only heat required to change the temperature of the bulb is that required by the specific heat of the bulb material and its enclosed liquid. Much depends upon the specific conditions of the application. In rapidly moving air, for example, time constants as low as 10 seconds are practical. When the bulb is immersed in a liquid the device may operate up to five times as fast.

The open type thermostatic assembly is used for some applications where cup type (fig. 1) may not fit. Operating principle is the same except that the bellows itself is filled with liquid and expands with rise in temperature to actuate the switch or valve rather than being compressed as in cup type.

Open assemblies require a heavier loading spring than the cup type. The bellows is more susceptible to damage due to handling and it is more difficult to mount this type of assembly. Cup assemblies are more rugged. They protect the bellows and apply the pressure to its outside surface. The bellows operates in compression — for which it is best suited—resulting in longer life.

Method of adjustment. Since liquid expansion with temperature is inexorable and produces great forces, adjustment of the system within its control range must be accomplished by providing for shifting the position of the switch or valve.

If you have an immediate problem, send a sketch showing controlling conditions. Clifford will send you additional data and recommend a suitable control.

Clifford Manufacturing Company, 139 Grove Street, Waltham 54, Mass. *Division of Standard-Thomson Corporation.* **Sales Offices in New York, Detroit, Chicago, Los Angeles, Waltham, Mass.**

Coefficients of Thermal Expansion

	Coefficient* (in.³/in.³/deg F) × 10⁻⁴ 0	5	10	Freezing Point (F°)	Boiling Point (F°)	Max. Op. Temp. (F°)
Mercury				−38	675	
H. T. A.†					672	600
Glycerine					554	350
H. T. C.†				29	529	700
H. T. B.†				54	599	700
Trichlorobenzene				65	415	450
o-Xylidine				3	592	450
Ethylene Glycol				11	388	350
Aniline				22	364	400
o-Dichlorobenzene				2	357	400
Chlorobenzene				33	271	400
Turpentine					315	350
Xylene				52	283	400
Monochlorobenzene				50	269	400
Glycerine-Water (67/33 vol.)				46	226	300
Toluene				139	231	400
Water				32	212	
Trichloroethylene				99	188	250
Benzene				42	176	300
Ethyl Alcohol				174	173	250
Carbon Tetrachloride				9	170	250
Methyl Alcohol				143	148	300
Chloroform				82	142	350
Acetone				138	133	350
F-113				31	118	250
Methylene Chloride				142	104	300
Ethyl Ether				177	94	250
F-12				158	75	250
Ethyl Chloride				218	55	300
F-11				168	48	250
Methyl Bromide				137	36	250
Butane				211	31	400
Sulphur Dioxide				103	14	600
Isobutane				229	10	400
Methyl Chloride				144	11	400
F-12				247	22	250
Ammonia				107	28	
Propane				310	44	400

* Values increase with temperature; for example, coefficient for trichlorobenzene ranges from 0.00044 in the region of its 45 F freezing point to 0.00070 at its recommended maximum operating temperature, 400 F.

† Special high-temperature service compounds.

Fig. 6. Representative filling mediums for liquid type assemblies.

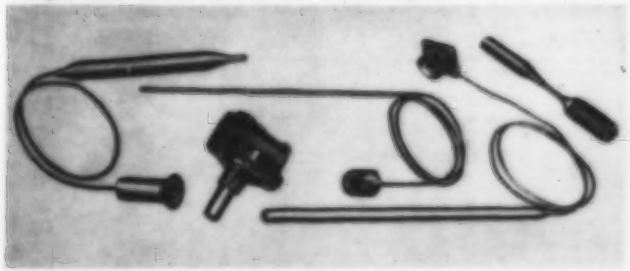
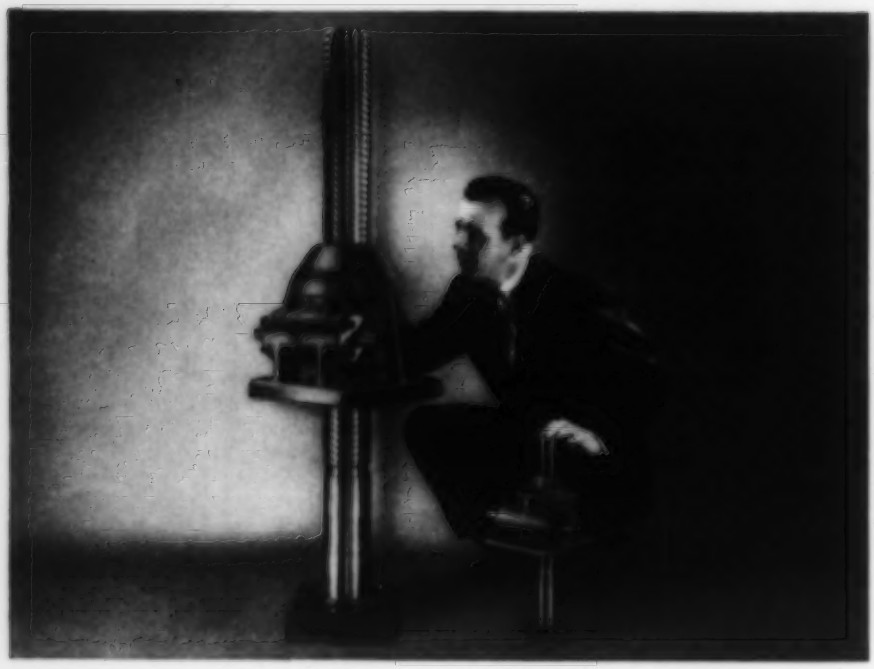


Fig. 2. Representative open type and cup type filled bellows thermostatic assemblies. Cup type is preferable being inherently stronger, easier to mount and with bellows protected from damage by handling.

Fig. 3. Electric and gas ranges are commonly equipped with liquid filled bellows controls. Bellows movement operates electric switches that turn heating elements on and off. In gas ranges bellows operates modulating valve to control flow of gas.

Fig. 5. Steam regulators are typical applications for liquid filled bellows assemblies. Cross section shows a Leslie Temperature Regulator used in cooling service. The rugged thermostatic element is adjustable over a temperature range of more than 600 F degrees.



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Recent Books

Protective Coatings for Metals. *Second Edition, by R. M. Burns, formerly director of chemical and metallurgical research, and W. W. Bradley, member of the technical staff, Bell Telephone Laboratories Inc.;* 640 *pages, 6 by 9 inches, clothbound; published by Reinhold Publishing Corp.,* 430 *Park Ave., New York* 22; *available from* MACHINE DESIGN, $12.00 *postpaid.*

This reference text has been designed primarily for those who have problems of protection against corrosion. As far as practicable, patented coatings and methods are so indicated in the references. Eighteen chapters cover principles, surface preparation, types of metallic coatings, sprayed metal, particular metallic and alloy coatings, noble and rare metals, test materials, organic coatings, anodized coatings, special-purpose coatings and rust inhibitors.

Protective Coatings is the second edition of an American Chemical Society Monograph Series reference. It includes new information and developments from World War II to the present.

•

Thermodynamics. *By Ray L. Sweigert, dean, graduate division, and Mario J. Goglia, professor of mechanical engineering, Georgia Institute of Technology;* 367 *pages, 6 by 9 inches, clothbound; published by Ronald Press Co., New York; available from* MACHINE DESIGN, $6.50 *postpaid.*

This textbook for junior engineering students presents a study of thermodynamics as one of the basic disciplines of engineering science. The first three chapters present essentials of the first and second laws of thermodynamics. Chapter 4 is concerned with properties of pure substance and per-

(*Continued on Page* 307)

The Engineer's Library

(*Continued from Page* 302)

fect gas, and Chapter 5 with processes in perfect gas. Chapter 6 takes up mechanics and thermodynamics of fluid flow. Chapter 7 on gases and vapors, develops a manner of presenting thermodynamic data for pure substance. Chapter 8 details properties of gas and gas-vapor mixtures. Chapter 9 presents rudiments of interrelation between thermodynamics and chemistry, and the final chapter introduces applied thermodynamics.

•

Dimensions and Tolerances for Mass Production. *By Earle Buckingham; 164 pages, 8½ by 11 inches, clothbound; published by The Industrial Press, New York; available from* MACHINE DESIGN, $8.00 *postpaid.*

This text deals with the problems of dimensioning and tolerancing mass-produced parts and assemblies. Methods and practices, in addition to current standards, are suggested to satisfy the need for coordination through all the various stages of product manufacturing, including product design, tool design, gage design, production and inspection. Particular chapters cover the need for an adequate system of dimensioning with tolerances; production design; detail drawings; tolerances on conditions of size, form and position; functional gages; surface finish; and case examples of the design of a 3-jaw chuck and a globe valve.

•

Aluminum Paint and Powder. *By Junius David Edwards and Robert I. Wray, both of Aluminum Co. of America; 219 pages, 6 by 9 inches, clothbound; published by Reinhold Publishing Corp., New York; available from* MACHINE DESIGN, $4.50 *postpaid.*

Directed to users and prospective users of aluminum powder in its various forms, this book provides information concerning present applications and is intended as well to stimulate new uses. Chap-

(*Continued on Page* 310)

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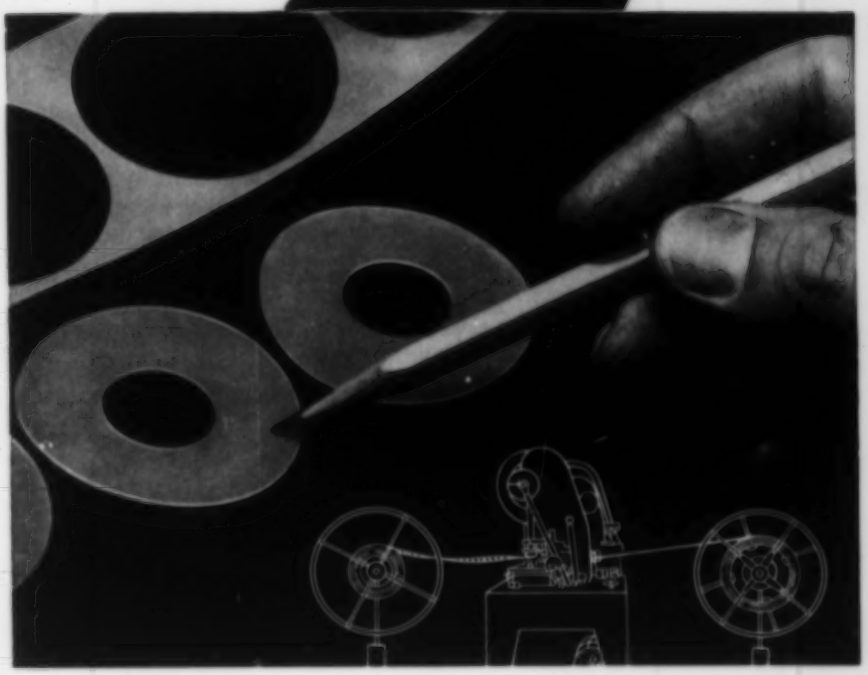

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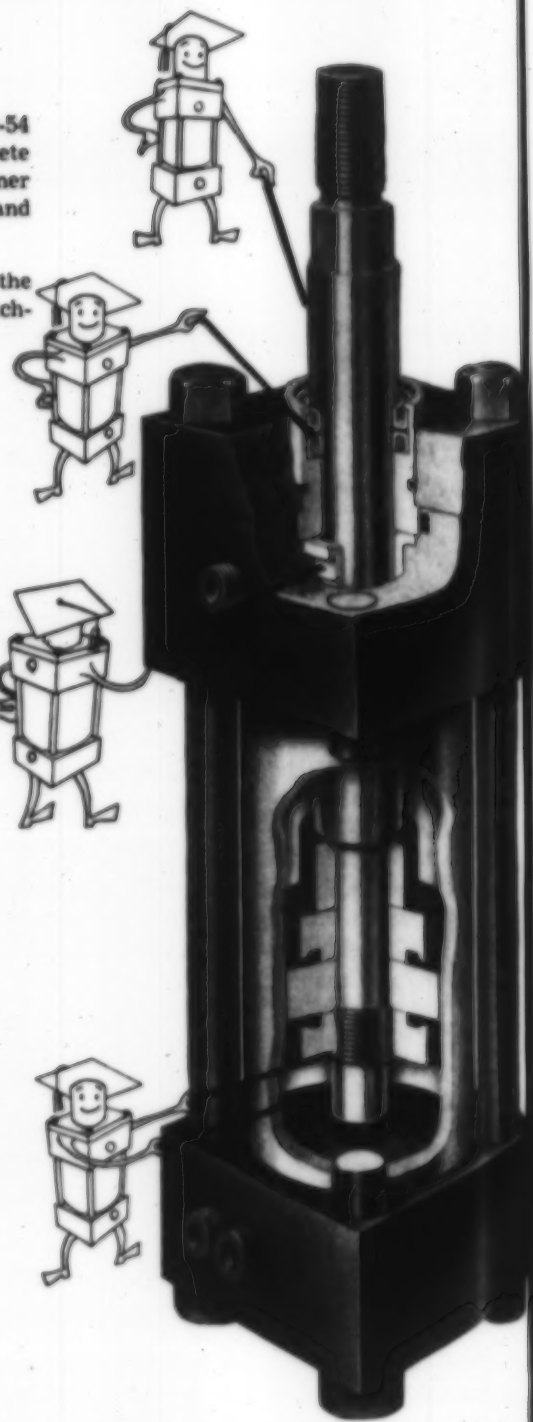
CASE-HARDENED Piston Rods (52-54 Rockwell "C") provide practically complete protection against damage from hammer blows, wrench-dropping, mishandling, and similar occurrences.

The HARD CHROME PLATING over the case-hardened rods protects against scratch-damage and rust.



TEFLON WIPERS

TEFLON HYDRAULIC ROD SEALS

Benefits To You

"TEFLON" Rod Wipers and "TEFLON" Hydraulic Seals withstand temperatures from —100° F. up to 500° F. They are impervious to practically all known chemicals, including the fire-resistant, special, and standard hydraulic fluids in current use.

RUST RESISTANT SURFACES

Benefits To You

Highest quality Black Ferric Oxide Finish provides rust protection in air cylinder operation and on all cylinders during shipping and installation.

Cylinder heads, caps, mountings, pistons, followers, and the unplated portions of the piston rods have this finish. It is not recommended for water service.

WRITE FOR CYLINDER BULLETINS H-104 and A-105

Complete Miller cylinder line includes: air cylinders, 1½" to 20" bores, 200 PSI operation; low pressure hydraulic cylinders, 1½" to 6" bores for 500 PSI operation, 8" to 14" bores for 250 PSI; high pressure hydraulic cylinders, 1½" to 12" bores, 2000-3000 PSI operation. All mounting styles available.

Over 8,000 Different Cylinder Selections Available for Immediate Delivery. Write for Complete List.

EFFECTIVE DATES

These new Miller features will be provided at no extra cost after January 1, 1956—and at Miller's option prior to that date.

SALES AND SERVICE FROM COAST TO COAST

CLEVELAND • YOUNGSTOWN • DAYTON • TOLEDO • CINCINNATI • COLUMBUS
PITTSBURGH • PHILADELPHIA • BOSTON • HARTFORD • NEW YORK CITY
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FORT WAYNE • SOUTH BEND • INDIANAPOLIS • MILWAUKEE • LOUISVILLE
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DENVER • ST. LOUIS • MOLINE • CHICAGO • HOUSTON • ATLANTA
TORONTO, CANADA and OTHER AREAS

Miller

MILLER FLUID POWER CO.

2006 N. Hawthorne Ave., Melrose Park, Ill.

AIR & HYDRAULIC CYLINDERS • BOOSTERS • ACCUMULATORS
COUNTERBALANCE CYLINDERS

(Advertisement)

Four More Miller Firsts . . .

Our "Report To Cylinder Users" was a simple statement of Miller Fluid Power Company's policy. In it was mentioned our dedication to the constant improvement of our products.

In line with this policy, here are new quality cylinder features that will eliminate many of the problems which you have reported to us.

Miller gave cylinder users one of its firsts when we chrome-plated all cylinder piston rods. Our reason was obvious. Chrome-plating gave every rod a mirror-like finish that no corrosive or abrasive dust could scratch. Miller made this chrome-plated, longer lasting rod standard. AT NO EXTRA COST.

Preventing Damage To Piston Rods

There were still plenty of hazards to which piston rods were subjected. A careless workman with a too handy wrench or pair of pliers meant a scored piston rod. A falling object striking the rod dented the softer metal beneath the plating of chrome. A jolt during assembly left its trouble-breeding mark. All of these nicked and scored the piston rods, damaging the whole assembly. Little could be done about this beyond repair and replacement—until the Miller announcement that from now on the piston rods on all cylinders—air and hydraulic—will be specially hardened (52-54 Rockwell C) to foil the carelessly used tool, the accident in transit or assembly, the falling object or unnoticed knock. Naturally, the new hardened rods will still be chrome-plated. Miller will now make this super quality an everyday standard. AT NO EXTRA COST.

Meeting The Challenge Of The New Demands On Seals

Rod seals on Miller hydraulic cylinders were constructed to be leakproof under all ordinary operating conditions. We guaranteed this. But we also stated in all our catalogues that for special conditions there must be special rod seals at an extra cost. Rod seals to withstand high temperatures had to be specially constructed. Where fire resistant fluids were used, special rod seals had to be provided at an extra cost. Because many fire resistant fluids destroy ordinary packing.

The present widespread use of these fluids and excessive heat generation from high speed operation and increased loads have resulted in reports of trouble on cylinders where ordinary seals were subjected to these hazards. These reports were not received with joy at Miller, even when the fault was definitely not ours. We don't like to have trouble develop on any Miller installation under any condition. So we decided to do something about these problems of the rod seals.

A new expensive material known as "TEFLON" has been developed for use as seals. This material is impervious to temperatures from —100° to plus 500° F. It resists all known fluids, even the most destructive of the fire resistant fluids. Now, every piston rod on every Miller hydraulic cylinder will be fitted with "TEFLON" Piston Rod Seals. AT NO EXTRA COST.

In addition, all rod wiper seals on all Miller Air and Hydraulic cylinders will be of the same chemical-and-heat resisting Teflon material.

These Teflon rod wiper seals will be standard on every Miller cylinder, regardless of how and where it will be used. This is Miller's way of doubly insuring cylinder users against all possible hazards. AT NO EXTRA COST.

Protection Against Rust

The barrels of Miller air cylinders are of moisture-resistant brass. The barrels of hydraulic cylinders, since they run in oil, are protected once they are installed and in operation. Beyond this all cylinder parts are subject to rust and corrosion. Such exposed parts as heads, caps and tie rods quickly show the unsightly evidences of rust. At least this has been so up till now. But all this is now being corrected.

From now on Miller will protect all these parts on both air and hydraulic cylinders with a black oxide process in which a chemically created ferric oxide coating is developed on the surface of the metal to protect against rust and other corrosion. Every Miller cylinder sold will carry this added protection. AT NO EXTRA COST.

These four new Miller firsts are added to the many firsts established by Miller. Like other Miller firsts which created new departures in cylinder design and construction, these are now offered as Miller standard specifications. AT NO EXTRA COST.

MILLER FLUID POWER COMPANY
2006 N. Hawthorne Avenue
Melrose Park Illinois

Another of the Reasons Behind Brad Foote Quality—

DEBURRING

• Deburring of gears isn't normally included in specs or drawings. And we don't get paid for it. But here at BRAD FOOTE we take pains and expend many man hours on deburring—for we know that one tiny burr can ruin a $100,000 machine.

• Examine your next shipment of gears. See whether your present supplier is painstakingly removing all the burrs. Find out how many hours your assembly department has had to charge against deburring. See another way in which BRAD FOOTE quality and extra attention to details saves you money.

• Prove to yourself the savings that BRAD FOOTE quality can mean. Let us quote on the gear requirements for your next program—whether it be radar equipment, diesel engines, etc. BRAD FOOTE has experience in providing gears for almost every specialized application and would welcome the opportunity of discussing your gear problems.

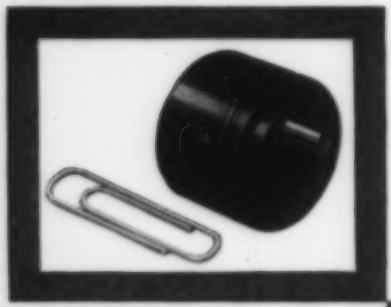
BRAD FOOTE MAKES ALL TYPES OF GEARS—IN A COMPLETE RANGE OF STYLES AND SIZES

BRAD FOOTE GEAR WORKS, INC.

1309 South Cicero Avenue • Cicero 50, Illinois

Bishop 2-1070 • Olympic 2-7700 • TWX CIC-2856-U

subsidiaries: AMERICAN GEAR & MFG. CO. • PITTSBURGH GEAR COMPANY



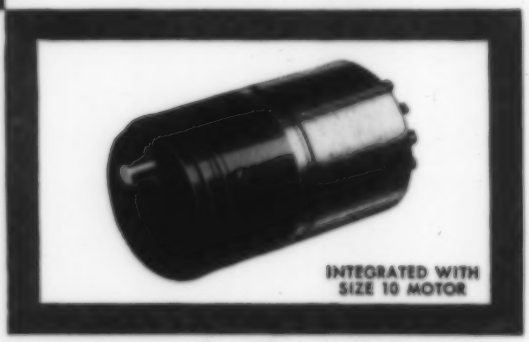
BOWMAR
PRECISION SUBMINIATURE MOTOR GEAR HEAD MODEL 937

APPLICATIONS:

Computers, Servo Controls and Instrumentation where light weight and low space factors are critical.

SPECIFICATIONS:

Ratio as Pictured: 26.4:1.
Dimensions: .937 in. dia., adds ⅝ in. to motor length.
Built-in Slip Clutch: Set at 10 in. oz.
Weight: 1¼ oz.
Backlash: Less than 30 min.



The subminiature "937" is one more example of Bowmar's design and production capability in the field of precision electromechanical components. If you have problems in these types of devices, you are invited to send your specifications to Bowmar.

Manufacturers of Precision Speed Reducers, Custom Electromechanical Assemblies and Mechanical Counters

Bowmar INSTRUMENT CORP.
2451 PENNSYLVANIA ST.
FORT WAYNE, INDIANA

FREE DATA "937"

The Engineer's Library

(*Continued from Page 307*)

ters cover the manufacture of aluminum powder, properties of aluminum powder and paste, the composition of aluminum paint, the use of aluminum paint in the protection of metals and wood, and special uses of aluminum paint including applications in the arts.

•

Professional Engineering Registration Laws. *Compiled by Alfred L. McCawley; 614 pages, 6 by 9 inches, clothbound; published by and available from Alfred L. McCawley, Trustee Publication Fund, Jefferson City, Mo.;* $8.75 *per copy.*

This volume is a compilation of the professional engineering registration laws of all of the states and Alaska, Hawaii, Puerto Rico and the District of Columbia. It covers in detail such elements of these laws as temporary permits, fees and bonds, the filing of maps, certificate applications, education requirements, examinations, and public works projects.

The planning and publication of the book was undertaken on the invitation of the National Society of Professional Engineers. Initial work on which the compilation is based had been done for the Missouri Board of Registration.

The book is planned to be a foundation volume under its present title, to be revised at intervals of ten years or less, as necessary. Between revisions it is to be kept up to date by cumulative supplements.

New Codes

Code for Pressure Piping. *ASA B31.1-1955; 136 pages, 8½ by 11 inches, paperbound; available from American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y.,* $3.50 *per copy.*

The purpose of the American Standard Code for Pressure Piping is to serve as a guide to state and municipal authorities in the drafting of piping regulations. The code serves also as a minimum safety standard for equipment manufac-

Belt Vibration is a Design Problem!

SOLVE IT BY SPECIFYING

VEELOS – the Balanced V-BELT

Read these typical reports on Veelos installations:

"On a water cooler that uses a gear pump with a fan assembly and radiator . . . I was able to *cut vibration 66%*. With Veelos adjustable v-belt, the machine could be shipped . . . when endless belts were used the machine was rejected."

"An oil cooler unit had been a trouble maker with many machines returned. Veelos adjustable v-belt was installed in place of endless belt and the amplitude was lower at every point. The vibration was as much as 76% lower with Veelos."

"On a precision grinder the finished work was not acceptable due to chatter marks. We found by using an electronic vibration analyser that the machine was vibrating .00035" at the spindle when operating with 7B endless v-belts. After balancing the grinding wheel the vibration was reduced to .00015" but the finished work was still not acceptable. I then installed 7B Veelos v-belts and the vibration was down to .00001" and the finished work was now acceptable."

IT WILL PAY YOU to specify Veelos adjustable v-belts because:

- **Veelos gives you efficient, vibrationless, full power delivery.**
- **Veelos gives you complete freedom of design . . . you fit the belt to the drive, not the drive to the belt.**
- **Idlers and pivoted or sliding motor bases are unnecessary.**
- **You can use outboard bearings to advantage. Veelos is installed without dismantling any part of the machine.**

Manheim Manufacturing & Belting Co.
606 Manbel St., Manheim, Pa.

I would like to see vibration reduction demonstrated on the electronic analyser. Have your representative call me for a convenient time.

Name_____

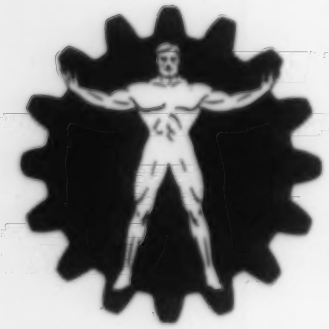
Company_____

Address_____

VEELOS
THE BALANCED
LINK V-BELT

Veelos is known as Veelink outside the United States.

ADJUSTABLE TO ANY LENGTH • ADAPTABLE TO ANY DRIVE



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The name you'll remember for

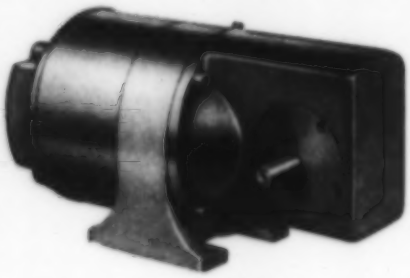
FINE PITCH PRECISION GEARS

LITTLE GIANT—the source that combines engineering experience and advanced low-cost production methods to supply the best possible gears at minimum cost. LITTLE GIANT carefully selects materials to specification. . .produces top quality, high precision gears with the latest machinery for hobbing, shaping, shaving and generating precision fine-pitch gears from raw material to finished gears. . .and maintains precision and quality through rigid inspection procedures after each operation.

SPUR GEARS—up to 4-pitch
HELICAL GEARS—up to 4-pitch
STRAIGHT BEVEL GEARS—up to 16-pitch
WORM & WORM GEARS—any size worm threads ground

and MODERN Gearmotors

Streamlined, modern design and precision gearing that produces exact rated efficiency characterize LITTLE GIANT Gearmotors. These LITTLE GIANT features assure dependable operation — integral ground worm and worm shaft . . . high nickel-bronze worm gear . . . precision-cut gears of highest quality materials . . . dust-proof, oil-tight close-grain semi-steel castings . . . oil seals that are leak-proof under high pressure. Output shaft mounts up, down, right or left — easily changed. A wide range of horsepower and torque ratings available.



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Mr. Design Engineer:

We offer you the Relay that eliminates controlled timing problems

★ No false contacts
★ Non sticking
★ Practically "fail safe"
★ Low cost timer

Durakool

STEEL MERCURY TIMERS

This steel clad, factory set, tamper proof Durakool timer-relay is practically non-breakable. Operating life multiplied 5 to 6 times by new plunger construction features. Any combination of operate-release time delays from 0.15 sec. to 20 sec.—either normally open or normally closed action.

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Send for Bulletin 800

The Engineer's Library

turers and engineers. It presents requirements for the selection of suitable materials, proper dimensional standards, the design of components, the erection of piping systems, and the testing of completed systems. This is the 1955 revision of the general code first published in 1935. In an appendix it itemizes similar but more specialized codes.

Association Publications

Interpretation of Engineering Data: Some Observations. *By Harold F. Dodge, quality results engineer, Bell Telephone Laboratories Inc., New York, N. Y.; 36 pages, 6 by 9 inches, paperbound; Authorized reprint from the Proceedings of the American Society for Testing Materials; available from the Society, 1916 Race Street, Philadelphia 3, Pa., $1.50 per copy*

Pertaining specifically to the field of quality engineering, this reprinted lecture emphasizes that (1) statisical methods and statistical thinking are highly useful in the interpretation of data, (2) most groups of engineering data can advantageously be regarded as samples, and (3) in the interpretation of data, the human element in the cause system reflected by the data is usually of first importance. The lecture includes numerous illustrations, examples and a bibliography of 19 items.

•

Fatigue of Aluminum. *By K. L. Templin, assistant director of research and chief engineer of tests, Aluminum Co. of America, New Kensington, Pa.; 59 pages, 6 by 9 inches, paperbound; Authorized reprint from the Proceedings of the American Society for Testing Materials; available from the Society, 1916 Race St., Philadelphia 3, Pa., $1.50 per copy.*

Mr. Templin observes that increased efforts of engineers to use metals more efficiently in machines and structures subject to repeated loads have resulted in more fatique failures in service. Under these conditions aluminum alloys generally behave like other commonly

DRY-TYPE TRANSFORMERS

NEW SOUND TESTING facilities, recently completed at the G-E Transformer Lab in Fort Wayne are designed to give you greater dependability for your transformer dollar.

ANOTHER SECTION of the G-E Lab is the electrical testing department. Here again, as in the noise and mechanical testing areas, your transformer quality is being assured.

G-E Transformer Lab Helps You Design for Highest Quality at Lowest Possible Cost

LET GENERAL ELECTRIC HELP SOLVE YOUR DESIGN PROBLEMS QUICKLY AND ECONOMICALLY

General Electric has made new additions to its dry-type transformer lab; modern testing facilities established for the purpose of developing and producing transformers which will meet your design specifications at the lowest possible costs. Because of this expanding production laboratory program, your toughest design problems can usually be solved with one of G.E.'s high quality standard lines.

IN RARE EXCEPTIONS where a standard G-E transformer will not fit your requirements, General Electric can still give you the most economical and highest quality transformer at the lowest possible price. No matter what your particular requirements may be, a G-E Transformer can solve your problem. All you need do is "specify your circuit requirements."

FOR FURTHER INFORMATION simply contact your nearest G-E Apparatus Sales Office, Distributor, or write Section 410-12, General Electric Company, Schenectady, N. Y.

GENERAL ELECTRIC

THESE THREE NEW General Electric dry-type transformers are more proof of the everyday efforts of the General Electric Specialty Transformer Laboratory to develop the latest in modern equipment to meet your most rigid design specifications.

NEW CONTROL TRANSFORMER

NEW TYPE "D" TRANSFORMER

NEW VOLTAGE STABILIZING TRANSFORMER

PLEASE, TELL US

The other day, one of our representative's salesmen, who had been picking up a lot of new air valve business, took the division manager out to show him how. He stopped in front of a likely looking plant, stuck his head out of the car and... listened! Sure enuff, thru the rest of the noises you could hear the hiss of air escaping. They went in and, you guessed it, a dud; no air valves in that plant. After two more such failures, the guy was ready to have his ears and head examined. A friendly passer-by restored his confidence by pointing out that his left rear tire was getting low.

Moral: If your interest in our ads is slowly leaking away because we are leaving out what you are most interested in, will you take half a minute and set us straight? Please, check only items you consider important when you want to read about air valves, and add your own comments.

- ☐ pressure range
- ☐ pipe sizes
- ☐ porting arrangement
- ☐ mounting arrangement
- ☐ leakage
- ☐ method of operation
- ☐ throttling
- ☐ materials
- ☐ dimensions of the valves
- ☐ handle load
- ☐ rate of flow
- ☐ typical installations
- ☐ user experience stories
- ☐ service data

remarks_____

I specify, order or requisition air valves for use in our plant ☐ for use on equipment we manufacture ☐ for pressures under 250 P.S.I. ☐ under 2000 P.S.I. ☐ under 4000 P.S.I. ☐ over 4000 P.S.I. ☐

Name_____ Title_____

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Address_____

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To get more useful information, let us know what you want in your valves. Our future ads will tell you how this vote came out. Clip out this tally sheet and send it to Barksdale Valves, 5125 Alcoa Ave., Los Angeles 58, California, and we will forward you immediately our air valve catalog.

SHEAR-SEAL AIR VALVES

LONG SERVICE

LOW MAINTENANCE

EASY THROTTLING

RUST FREE MATERIALS

A review of the patented "Shear-Seal" principle reveals the secret of its success. The sealing surface of the self aligning tubular seal and the mating surface of the rotor are in constant intimate contact. Flow is through the seals, never across sealing surfaces. Actually, their sealing quality improves with use, as a result of the lapping action of each valve operation. These characteristic design features of long lived, service-free operation are borne out by users' experience, particularly in the control of unlubricated air or other dry gases.

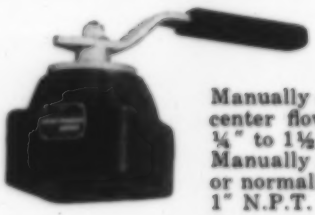
The excellent throttling possible with these valves is again a direct result of the "Shear-Seal" design. As there is no spool or poppet to buck the force of flow, the handle moves with equal ease whether you open the valve a little or a lot.

Corrosion is banned from Barksdale air valves and with it the resultant binding and galling; only rust free materials are used, such as stainless steel, bronze, aluminum, etc.

If all that sounds expensive, it is not; the ¼" valve for 250 P.S.I. service retails for $18.50, less O.E.M. and quantity discounts.

250 P.S.I. SERIES

Manually and foot operated 4-way valves. Available with spring return to center, to reverse or without spring return. Port sizes ¼" and ⅜" N.P.T.



2000 P.S.I. SERIES

Manually operated 4-way valves with open center or closed center flow pattern. Available in standard porting from ¼" to 1½" N.P.T. or equivalent sizes of manifold porting. Manually operated manipulator valves with normally open or normally closed center, in standard porting from ¼" to 1" N.P.T.

Manually operated shut-off valves in standard porting from ¼" to 1" N.P.T.

4000 P.S.I. SERIES

Manually operated 4-way valves in standard porting from ¼" to 1½" N.P.T. and manifold porting equivalent to ¼" only.

Manually operated shut-off valves in standard porting from ¼" through 1½" N.P.T.

The complete range of air valves is fully catalogued in bulletin A-5.

BARKSDALE VALVES

5125 ALCOA AVENUE, LOS ANGELES 58, CALIFORNIA

Branches and representatives in all major trading areas.

there really is a
World of Difference
in Bearings
Prometl
Engineered Bronze
BEARINGS-BUSHINGS
WEARING PARTS
Standard and special formulas developed for specific or unusual conditions. Assure the best combination of physical properties, strength in tension and compression, hardness and ability to sustain both static and dynamic loading. Protect moving parts from injury, scoring, and seizing due to temporary interruption or failure of lubrication. Will not powder under the most severe conditions of service. Available rough cast or machined to precisely controlled tolerances. Can be machined at surface speeds up to 875 lineal feet per minute. Castings to your patterns, any size, shape or section, delivered as scheduled and specified. Pattern making, designing and machining when required.
Write for free literature and service data sheets. Send blueprints, conditions of operation and other data for recommendations and quotations. You are invited to discuss your bearing problems with our metallurgists, engineers and laboratory technicians.
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The Engineer's Library

used metals but with significant differences. The lecture summarizes knowledge on fatigue of aluminum to the end that aluminum structures and machines, subject to repeated loads, will last longer. An extensive bibliography (497 items) is also provided.

•

A Glossary of Terms for Fluid Power. 11 *pages,* 8½ *by* 11 *inches, paperbound; available from National Fluid Power Association,* 1618 *Orrington Ave., Evanston, Ill.,* 20 *cents per copy (stamps accepted).*

This booklet contains alphabetically listed definitions of terms commonly used for hydraulic and pneumatic equipment.

•

Design, Operation and Maintenance of Hydraulic Equipment for Use with Fire Resistant Fluids. 20 *pages,* 8½ *by* 11 *inches, paperbound; available from National Fluid Power Association,* 1618 *Orrington Ave., Evanston, Ill.,* 30 *cents per copy (stamps accepted).*

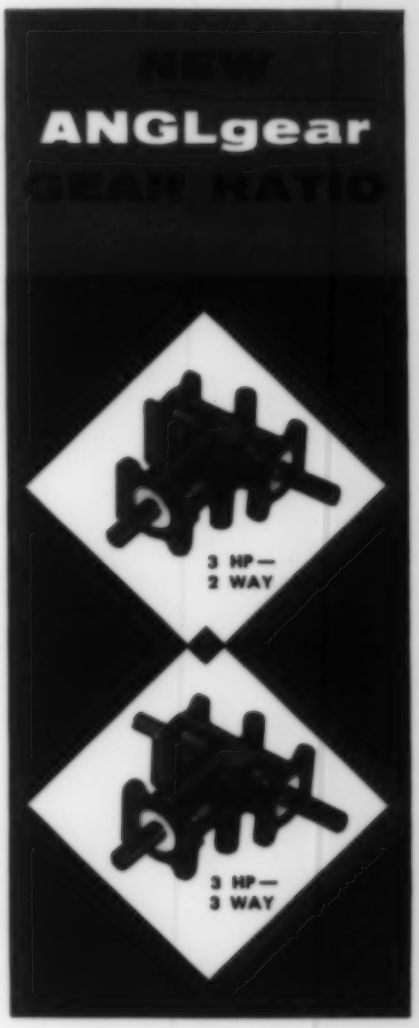
This report presents general information on basic characteristics of fire resistant fluids most commonly used in industrial hydraulic equipment. It discusses how these fluids should be introduced into present systems or designed into new ones.

•

Proceedings of the Conference on Professional Development—The Responsibility of Industry and the Engineer. 56 *pages,* 6¾ *by* 9½ *inches, paperbound; available from National Society of Professional Engineers,* 1121 15*th St. N.W., Washington* 5, *D. C.,* $4.00 *per copy, or* $2.00 *for NSPE members.*

This booklet is a complete transcript of the conference on professional development held in June, 1955, in conjunction with the annual meeting of the National Society of Professional Engineers. It contains five talks, other speeches and a panel discussion by leaders

(*Concluded on Page* 318)



2-1
plus new HP!

The right angle take-offs shown above — our largest 2 and 3-way ANGLgear models — are offered now with 2-1 gear ratio. They've also been up-rated to 3 hp at 1200 rpm.

The ANGLgear line — which also includes 1/3 and 1 hp units, with either 1-1 or 2-1 ratio — has long won acclaim in many fields for compact design and durability. They're sold only through your local distributor. See our literature in the product design section of Sweet's Catalog.

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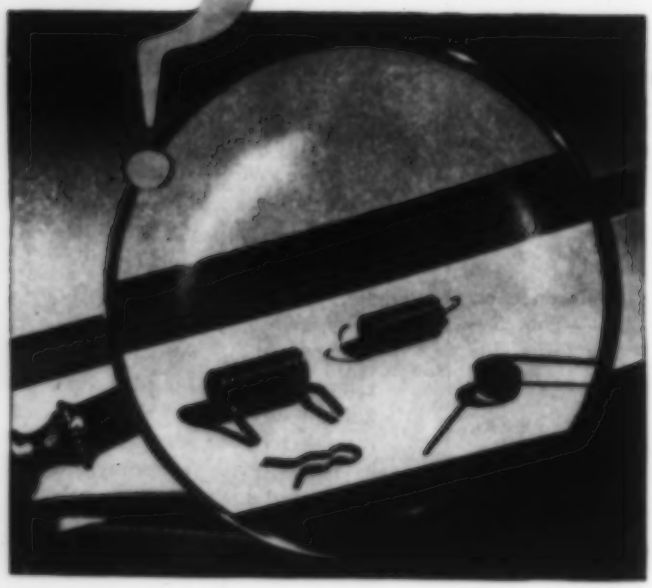
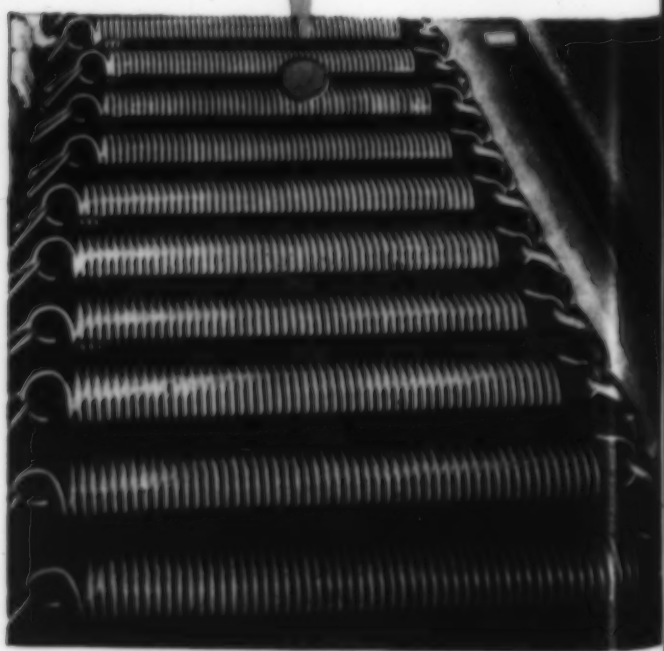
ACCESSORIES CORPORATION
HILLSIDE 5, NEW JERSEY

BIG springs?

-little springs



-simple springs



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-tricky springs

SOME OF OUR BEST CUSTOMERS still find it hard to believe that American Steel & Wire can turn out such an incredible variety of springs: we make extension springs, compression springs, torsion springs, motor springs, flat spiral springs, flat springs, and wire forms with an endless variety of end formations. Cold wound, hot wound and heat treated.

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Finishes? Springs can be supplied ground, polished, shot blasted, ball blasted; coated with japan, lacquer, zinc, cadmium, copper, nickel or just about any other material that can possibly be applied.

American Steel & Wire can supply completely fabricated spring assemblies, too. A complete assembly department can produce, *at low cost*, such items as parking brake assemblies.

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USS

USS AMERICAN QUALITY SPRINGS

UNITED STATES STEEL

Universal SPECIAL CS
SHAFT TYPE OIL SEAL
WITH 8 BIG ADVANTAGES

- High speeds improve efficiency.
- Low friction.
- Long, trouble-free life.
- Ideal for high operating temperatures.
- Permits greater shaft eccentricity.
- Unaffected by sudden acceleration.
- No replacement problems.
- Nominal cost.

WRITE FOR DESCRIPTIVE LITERATURE

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(*Concluded from Page* 315)

in engineering administration and education.

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The Businessman's Guide to Government Information and Advice. *Edited by Sherman S. Cohen, vice president and general counsel, American Association for Public Information, Education and Research;* 97 *pages,* 5 *by* 8¾ *inches, paperbound; published by and available from the Association,* 1010 *Vermont Ave. N.W., Washington* 5, *D. C.;* $1.00 *per copy.*

This booklet is intended to serve as a businessman's guide to government services. It is divided into three main parts entitled: Information and Advisory Services of the Federal Government, Selected Bibliography of Government Publication, and Directory of Federal Statistical Personnel.

Government Publications

NACA Technical Series. *Each publication is* 8 *by* 10½ *inches, paperbound, side-stapled; copies available from National Advisory Committee for Aeronautics,* 1924 *F St., N.W., Washington* 25, *D. C.*

The following Technical Memorandums are available:

1330. **Theory of Dynamic Creep**—12 pages.

1390. **On the Mechanism of Buckling of a Circular Cylindrical Shell under Axial Compression**—46 pages.

The following Technical Notes are available:

3293. **Cumulative Fatigue Damage of Axially Loaded Alclad 75S-T6 and Alclad 24S-T3 Aluminum-Alloy Sheet**—49 pages.

3412. **Creep and Creep-Rupture Characteristics of Some Riveted and Spot-Welded Lap Joints of Aircraft Materials**—53 pages.

3443. **Shearing Effectiveness of Integral Stiffening**—37 pages.

3460. **Tables of Coefficients for the Analysis of Stresses about Cutouts in Circular Semimonocoque Cylinders with Flexible Rings**—98 pages.

3462. **Tensile Properties of 7075-T6 and 2024-T3 Aluminum-Alloy Sheet Heated at Uniform Temperature Rates under Constant Load**—46 pages.

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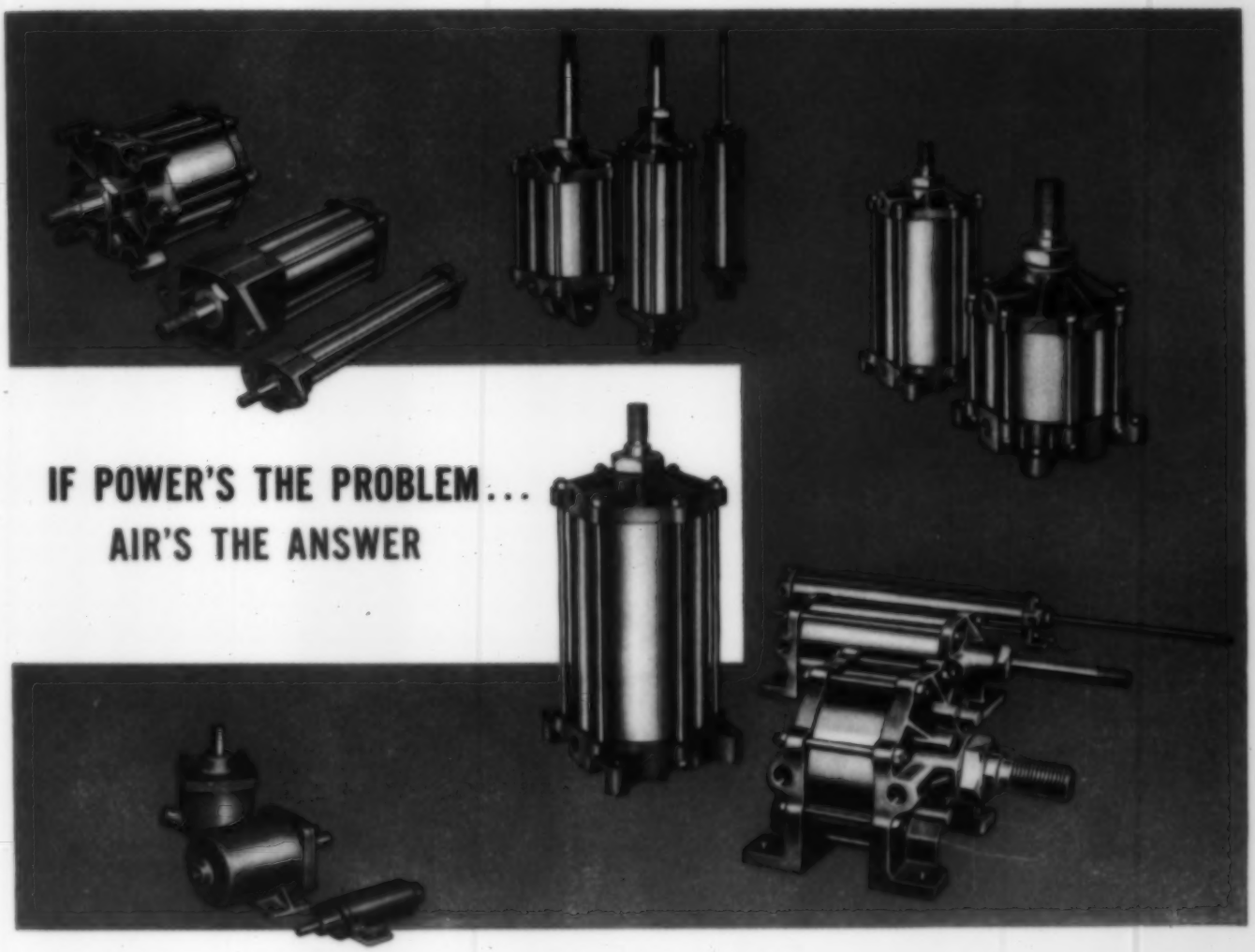

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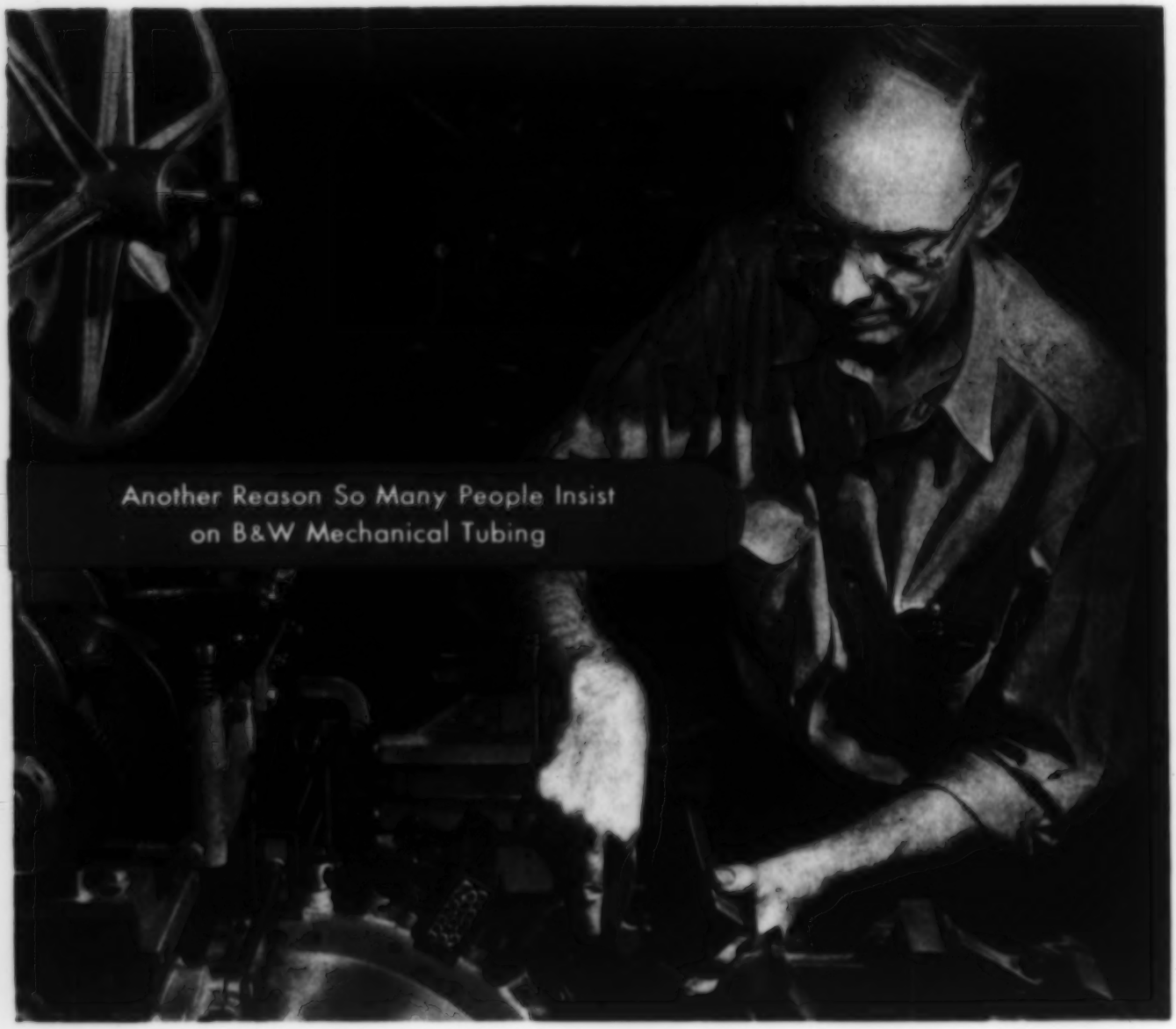

SNUG ARBOR "PUTS THE SQUEEZE" ON CIGARETTES

Smoking pleasure, represented by Viceroys, Kools and Raleighs, is packaged faster than the eye can follow—7500 packs per machine per hour—at the Brown & Williamson Tobacco Co. plant in Louisville, Kentucky.

Heart of the unique packaging machine is the thin metal cigarette arbor, slightly narrower but longer than a cigarette package, perfectly smooth inside and out; strong enough to maintain its shape in use. Cigarettes, pushed through the arbor into the paper pack, expand slightly to make the tight, crisp package so familiar to smokers. Carbon steel arbors, previously used, required considerable time and labor to prevent rust, corrosion and splitting before and during fabrication.

In 1953, Brown & Williamson called in The Babcock & Wilcox Company whose tubing specialists studied the problems and suggested the use of B&W Croloy 18-8S, Type 304, Stainless Steel Mechanical Tubing, supplied in rectangular shape to Brown & Williamson specifications. Rust, corrosion and splitting during fabrication have been eliminated with estimated savings of 15 per cent.

You can "put the squeeze" on your operating time and costs by starting with the *right* B&W Mechanical Tubing —carbon, alloy or stainless—for your requirements. Mr. Tubes, your link to B&W, is ready, willing and able to give you the benefit of his long experience. Or write for Bulletin TB-361. MD.

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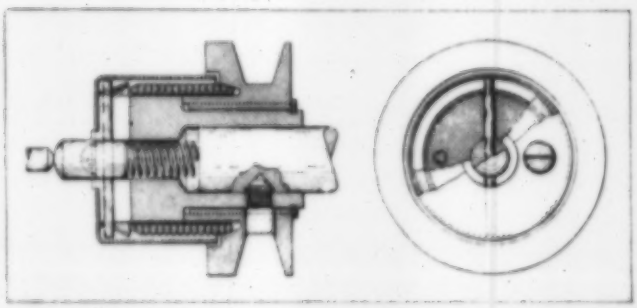
TA-5043M

NOTEWORTHY

Patents

Overrunning Clutch

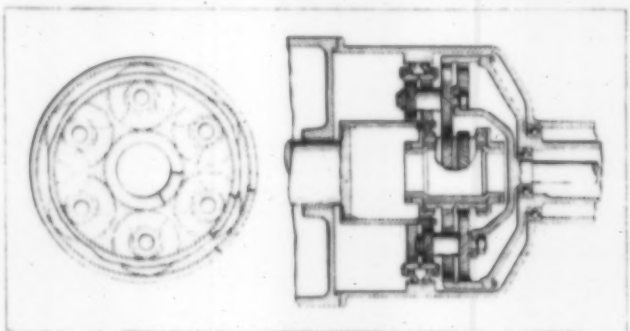
One-way clutch for light loads utilizes a helical spring as the power transmission element. The driven clutch member consists of a drum around which is wrapped a helical spring. One end of the spring fits into a tapered groove in the driving member.



In operation, a conical-shaped sheet-metal ring, actuated by a manually-operated spring-loaded plunger, compresses the helical spring, causing it to tighten around the drum. At the same time the opposite end of the spring is forced into the tapered groove, locking both clutch elements together. *Patent* 2,700,442 *assigned to Marquette Metal Products Co. by S. F. Gorske.*

Equalized Planetary-Gear Drive

Uniform gear tooth loads are assured in a planetary gearing system designed to provide two power flow paths from an input shaft to coaxial output shafts, rotating in opposite directions. Equal amounts of



power are supplied to the two output shafts through two planetary-gear trains in which the sun gears and two auxiliary reaction gears are designed to "float" to equalize tooth reactions between the sun and planet

(*Continued on Page* 324)

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Clutch Head® screws with their famous "lock-on" feature permit quick assemblies in those troublesome, "hard-to-get-at" spots. It frees one hand, too, permitting the operator to hold the part in place while driving the screws, and automatically unlocks as the screws are driven.

No need to throw your driver away just because it is worn at the point—just grind it back and you have a new bit.

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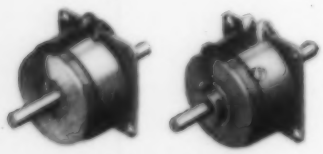
MAJOR IMPROVEMENTS in performance of machinery are now being made without major redesign or expense through the application of Warner Electric Motion Control. The reason is the armature and magnet assemblies of Warner Electric Brakes, Clutches, and Clutch-Brakes can easily be installed by a variety of methods to suit space requirements and the existing design of machinery.

Electric Brakes, Clutches, and Clutch-Brakes

Five standard sizes ranging from 40 to 700 lb-ft, maximum static torque rating. Energized by 25-35 watts of 6 or 90 v d-c.



Small "SF" and "RF" Line

Three sizes ranging from 8 to 240 lb-in, maximum static torque rating. Energized by 6 to 9 watts of d-c.

Large "SF" and "RF" Line

Four sizes ranging from 125 to 700 lb-ft, maximum static torque rating. Energized by 25-35 watts of d-c.

With the exception of certain tolerances, practically the only limitation to the way unit assemblies can be arranged is that the armature and magnet surfaces be in contact. Magnet assemblies can be mounted from the *inside* or *outside* by a flange. Armature drive pins can be mounted directly to a drive sheave, sprocket, gear, or other moving part . . . or back-to-back with the armature of another Warner unit. Gear-type hubs permit mounting the armature to a split shaft for clutch-coupling or clutch-brake coupling applications. Clutches and brakes may be mounted together for fast, accurate stop-start control. Individual units mounted at different points on the machine give you the same precise operating characteristics.

Electro-magnetic control of lineal and rotary motions is an important "break through" for automation minded machine designers. For, now electrical devices such as limit switches, relays, electric eyes, electronic controls, etc. can be used to make machines more articulate and automatic. If you have a stopping, starting, inching and jogging, lineal positioning, rotary indexing, interlocking, or tension control problem, send for a copy of this new application analysis report, which illustrates methods of installation and design principles which have successfully solved difficult machine design problems, increased production, reduced manufacturing costs, and added new sales features to machinery.

DESCRIBES 6 EXCLUSIVE ENGINEERING FEATURES THAT MAKE YOUR MACHINES MORE SALEABLE. These include: (1) faster and smoother starts and stops—no translation time during engagement of armature and magnet; (2) minimum shock to gear trains and machinery—progressive torque build-up absorbs backlash and windup in gear trains and shafts; (3) no adjustment needed—no bands, links, cams, or adjusting screws; (4) infinite control of torque—rheostat control permits stepless adjustment of acceleration and deceleration; (5) minimum shaft space required—elimination of sliding yokes and jaw-type engagements saves space; (6) rapid heat dissipation—segmented armature dissipates heat and fluted backing plate gives cooling action.

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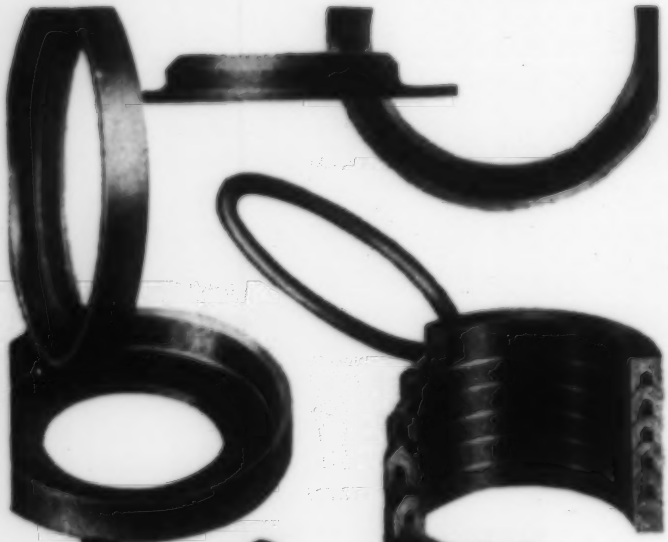

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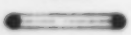
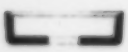
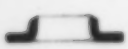
PALMETTO PYRAMID®—The champion where a multilip seal is preferred. Rugged design offers plus service life when used as a rod, ram, plunger, or piston seal at high pressures.



PALMETTO O-RING—A popular seal for low and medium pressures. Simplifies design—saves space. Also recommended for gasket applications.



PALMETTO KUP—A popular piston packing available in a variety of fabrications to seal the standard or new synthetic fluids. More resistant to heat than leather ... will not dry out in air.



PALMETTO FLANGE—For rod packing in low pressure service. Adaptable to reciprocating or rotary motion. Also used as dust seal.

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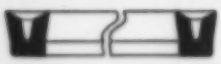

PALMETTO U-RING—New rugged design with wide lip flare for use in cylinders made from commercial tubing honed up to .030 over nominal sizes. Same sizes available in synthetic or fabric construction permits interchangeability of packing in low or high pressure cylinders. ALLOWS STANDARDIZATION OF COMPONENT PARTS ... INCREASES EFFICIENCY ... REDUCES FRICTION. ALSO RECOMMENDED AS ROD SEAL.

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GREENE, TWEED & CO. North Wales, Pa.

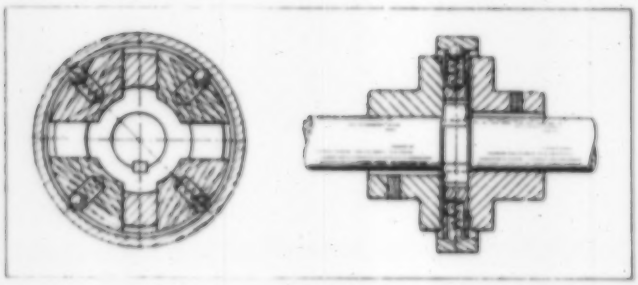
Noteworthy Patents

(*Continued from Page* 321)

gears. The planet gears of the two gear trains are fixed to one of the output shafts and mesh with ring gears fixed to the other output shaft. The floating actions of the sun and reaction gears tend to divide the load equally between the two gear trains. *Patent* 2,700,311 *assigned to Falk Corp. by A. G. Bade.*

Flexible Shaft Coupling

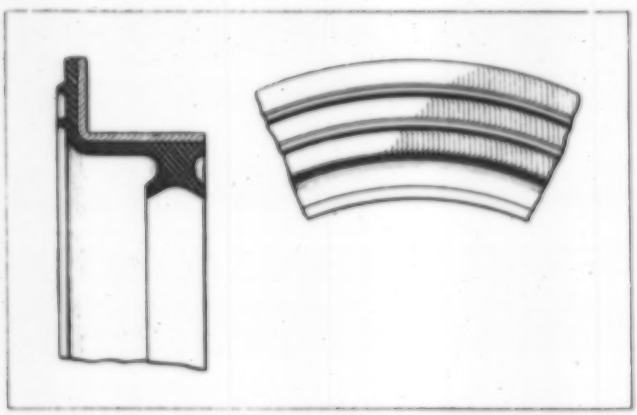
Misalignment-compensating coupling is designed to transmit high-torque loads. Floating segments placed between lugs on the driving and driven coupling elements permit off-center operation and a limited



amount of relative end movement of the connected shafts. Spring-loaded balls hold the floating segments in place within a ring housing. Localized pressures, which lead to excessive wear are eliminated by the segment construction which assures adequate bearing surface to distribute the operating load. *Patent* 2,698,529 *assigned to American Flexible Coupling Co. by R. H. Shenk.*

Leaktight Shaft Seal

Sealing element of a rotating shaft seal is a rubber diaphragm of L-shaped cross section. Dual flexible lips on one leg of the L form a leaktight seal at the



surface of the shaft. Molded projecting ribs on the other leg provide a face seal at the housing flange. A metal ring of matching L-shaped cross section reinforces and stabilizes the flexible diaphragm. *Patent* 2,702,203 *assigned to Chicago Rawhide Mfg. Co. by J. H. Sefren and J. C. Eirk.*

SSW forged rings take rugged, heavy wear of Heyl & Patterson coal breakers

SSW forged rings consistently have proven to Heyl & Patterson, Inc., Pittsburgh, they can take the rugged, heavy wear of their coal breakers. They've found Standard Steel's inherent uniform structure and high-quality analysis makes for longer-lasting, failure-proof life of these rings.

This 19-ft. long, 35-ton coal breaker revolves on two 13-ft. diameter endless forged steel tires. It's capable of producing approximately 600 tons of coal per hour, turning at 15 rpm. And Heyl & Patterson can count on these precision-treated rings to withstand effectively abrasion and wear of such heavy-duty operation.

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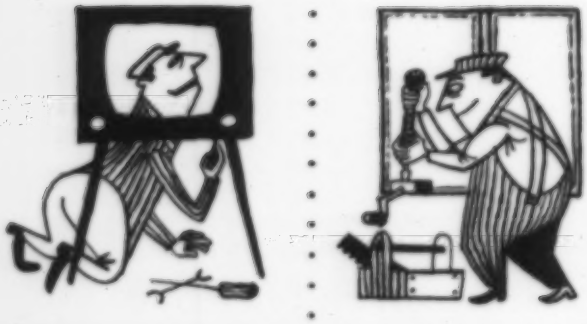

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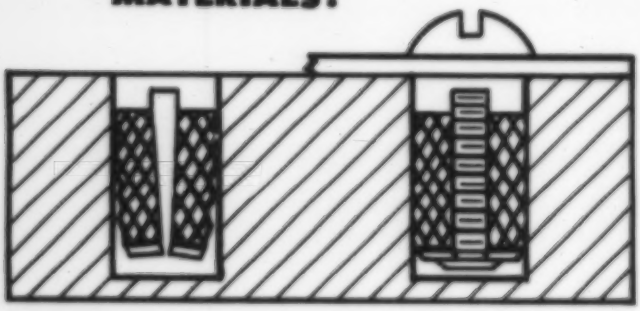

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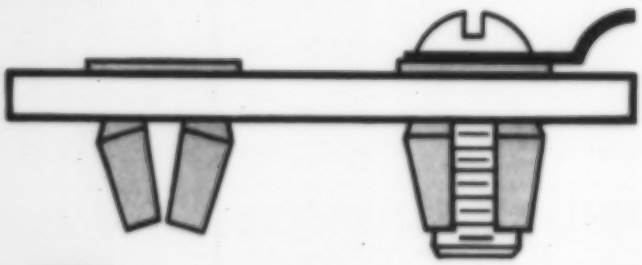

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AIRCRAFT NUT CORPORATION

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Noteworthy Patents

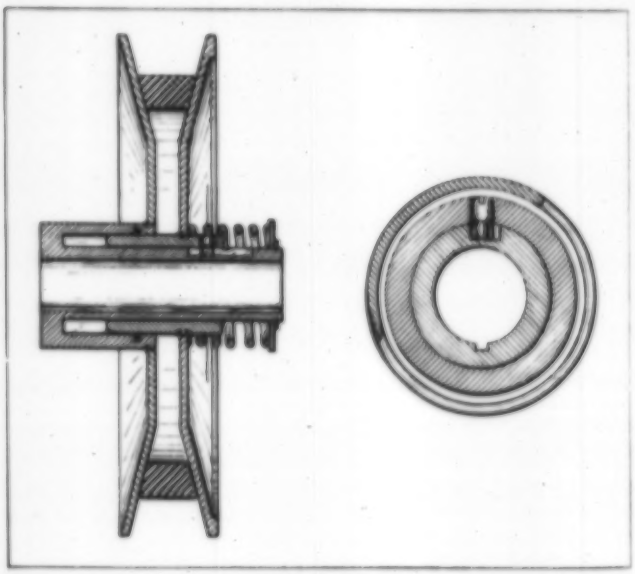
Multifunction Jaw Clutch

Selective control of power transmission in rotating shaft connections is offered by a jaw clutch designed to provide three operating functions. With the clutch jaws fully meshed, a rigid shaft connection is obtained, permitting rotation in both directions with either shaft driving. With the clutch jaws partially engaged, the unit operates as an overrunning clutch.

The latter action is accomplished by means of beveled edges on one side of each of the clutch jaws. One clutch member is spring loaded, permitting it to ride over the beveled edges in one direction of rotation; reversal of rotation, however, results in positive engagement of the unbeveled jaw sides. A third position completely disengages the clutch members. *Patent* 2,699,852 *assigned to Marmon-Herrington Co. Inc. by W. A. Cost.*

Variable-Pitch Sheave

Compensation for belt tension variations in V-belt drives is accomplished by a sheave designed to adjust pitch automatically. A cam arrangement between the sheave flanges acts to assist a compression



spring in resisting separation of the flanges under load. A relatively light spring may thus be used, increasing sensitivity to belt tension changes and eliminating the possibility of excessive belt squeeze under running conditions. *Patent* 2,699,071 *assigned to Miner Pulley & Transmission Co. by C. H. Miner.*

From a dream-world marriage of mathematics and electronics...tomorrow's oil seals today

Looks simple, doesn't it—the oil seal pictured here. Actually, it's a precision assembly of high tolerance parts, each the product of painstaking engineering.

One such part is the unseen but vital tension spring behind the sealing lip. Thousands of these springs—all different—are needed in the broad line of National Oil Seals. Each spring must have exactly the size, coil diameter, tension, spring rate, and heat treat required for the oil seal it fits.

Done the conventional way, calculations of characteristics for thousands of springs would take months. So, National Oil Seal Engineers developed new mathematical methods which, in combination with Univac, permit specifications to be determined at speeds up to 150 per minute.

This fortunate marriage of mathematics and electronics is another example of efficient, "future" National Oil Seal engineering—and another reason why National consistently brings you tomorrow's oil seals today.

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New Sealing Lip Design. Recent development of NMB Engineering is new lip design. New features include long, thin lip section and small coil diameter tension-spring. Contact on shaft is light, yet effective sealing is maintained throughout long service life.

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BALL BEARING MOTORS

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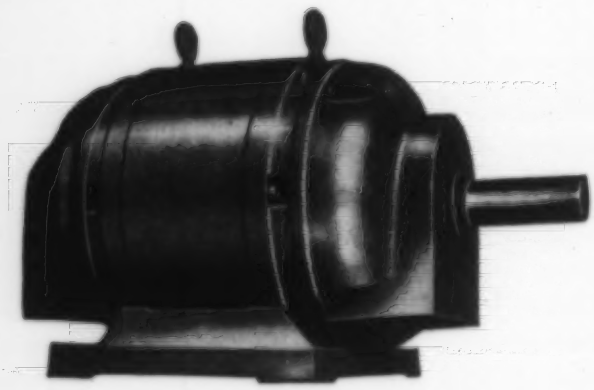

When specifying the power unit for your machinery, bear these exclusive VALLEY features in mind!

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New Machines

Domestic

Washers and Dryers: New line of home laundry equipment includes automatic and semiautomatic washers, and automatic electric dryers. Automatic washers have three-way agitator with rubber fins; perforations in the shaft eject jets of water during washing cycle. All models have gearless drive, adjustable leveling legs, automatic emergency cut-off. Motor is 1/3-hp, 115 v, 60 cycle, permanently lubricated. Washers are 25 in. wide, 28¼ in. deep. They hold up to 9 lb of dry clothes. Dryer design includes a safety thermostat, adjustable leveling legs, porcelain-lined cylinder, and a safety door which stops motor and heating element when opened. Belt-driven cylinder and blower are powered by 1/6-hp motor. Models are 36 in. high, 30 in. wide, and hold up to 18 lb of wet clothes. All washers and dryers are available in three colors and white. *American Motors Corp., Kelvinator Div., Detroit, Mich.*

Typewriters: Two new portable typewriters incorporate two-tone color styling, extended paper support and improved carriage rail construction. *Underwood Corp., New York, N. Y.*

Heating and Ventilating

Exhaust Fan: Model K Ventura fan is designed specifically for heavy-duty industrial use. Inlet permits free flow of air with minimum resistance in exhausting smoke, fumes and other contaminants. Fans are available in capacities of 587 to 12,500 cfm and with two-speed or constant-speed, direct-drive, totally enclosed motors. *American Blower Corp., Detroit, Mich.*

Centrifugal Fan: Type BC centrifugal airfoil fan has backward-curved, all-aluminum blade design which provides freedom from air flow separation at normal working pressures. Sparkproof construction meets requirements for both Class I and II hazardous environments, permitting operation at a maximum tip speed of 13,500 fpm. Six basic sizes are available, each with either direct-connected or belt drive. Choice of dual-voltage motors in direct-connected type includes 115/230 v, 1-phase, or 220/440 v, 3-phase. Three housing finishes are available for strong acid or alkali conditions, excessive moisture or mild acid conditions. *Ilg Electric Ventilating Co., Chicago, Ill.*

Metalworking

Band Saw: Fourteen-inch band saw has eight-speed drive and accessible clutch on the end of the lower wheel shaft, permitting rapid change-over without removal of V-belts except in the transition from lower four to higher four speeds. Range of speeds is from 40 to 335 fpm for metal cutting and 40 to 3000 fpm

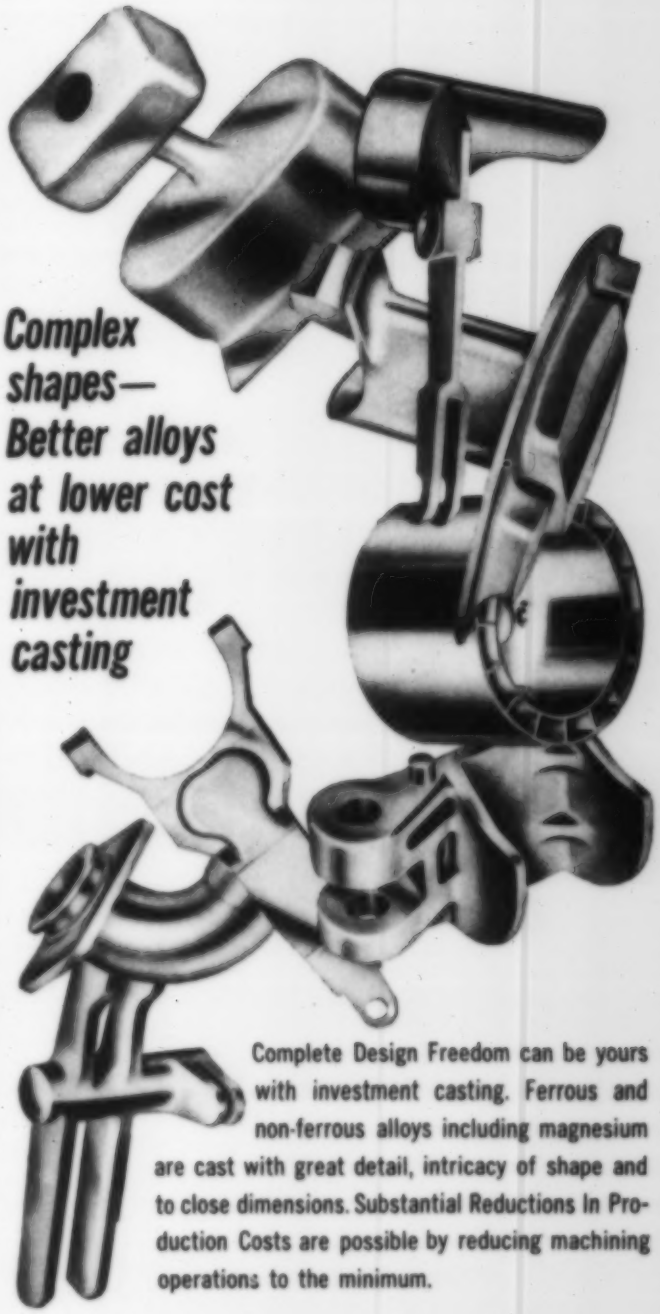
for wood cutting. Lowest speed is for cutting of stainless steel and forgings; higher speed facilitates cutting of wood, fiber and plastics. Saw accepts conventional hard-edge metal-cutting blades, standard wood-cutting blades or skip-tooth blades for wood, plastics and nonferrous metals. *Rockwell Mfg. Co., Delta Power Tool Div., Pittsburgh, Pa.*

Milling Machines: Dial type milling machines have a wide range of speeds and feeds for operations on light metals and tougher alloys. Built in three sizes with three styles for each size, the models have spindle speed ranges of 18 to 1800 rpm for the smallest size and 16 to 1600 rpm for the two larger types. Speeds are indicated by a large dial and selected by pushbuttons. Spindle drive motors for the three sizes are 10, 15 and 20 hp. Pushbuttons are used for starting and stopping spindle drive, motor and coolant pump. Thirty-two feeds from $\frac{3}{8}$-in. to 90 in. per minute are selected with a knob. Rapid traverse, through independent 3-hp motor drive, is 150 in. per minute. Cutting fluid pump is also individually motor driven. Plain and vertical machines are available with or without automatic table cycles. *Cincinnati Milling Machine Co., Cincinnati, O.*

Drill-Tapper: Cleveland Jr. Multi-Spindle drill-tapper is designed for multiple small-hole drilling and tapping in high-speed production. The machine drills eight holes up to No. 25 drill size or taps eight holes up to 10-32 in mild steel at one operation. Spindle speed is 2700 rpm. Operating speed is approximately 1200 strokes per hour. Minimum spindle spacing is $\frac{3}{4}$-in. within an 8-in. bolt circle. Machine has a stroke of 4 in. Clearance between spindle nose and table may be adjusted from 1 to 12 in. Motor is 1 hp, 3-phase, 60 cycle, high reversal vertical type which operates continuously in one direction for drilling and may be reversed in tapping. No machine adjustment is required to change from one operation to the other. The drill-tapper is 82 in. high. *Cleveland Tapping Machine Co., Canton, O.*

Air Shear: Type O-SC-20 air shear has 10-in. knives, with four cutting edges which can be adjusted by setscrews after grinding. It operates from any standard shop air supply or compressor at pressures from 60 to 125 psi, cutting $1\frac{3}{4}$-in. diameter cold mild steel at 80 psi air pressure. Normal speed is 2 seconds per cycle. This shear has no motors or gears and operates only while cutting. Unit is 48 in. high, 21 in. wide and 62 in. deep. Jaws open $4\frac{1}{2}$ in. and are located 36 in. above the floor. Overloading will not harm the equipment. *Curry Air Shear Corp., Pittsburgh, Pa.*

Boring Machine: Style 432 vertical precision boring machine performs turning, boring, facing, grooving and chamfering as separate or combined operations. Each of two stations has a separate hydraulic system, counterweighted compound tool slide, vertical spindle, drive equipment and controls. During the machining operations at one station, the other station can be unloaded, loaded and started on its automatic cycle. Individual controls and power equip-



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